INTERAVIA

REVIEW OF WORLD AVIATION

IN THIS ISSUE

Guided Missiles 1956

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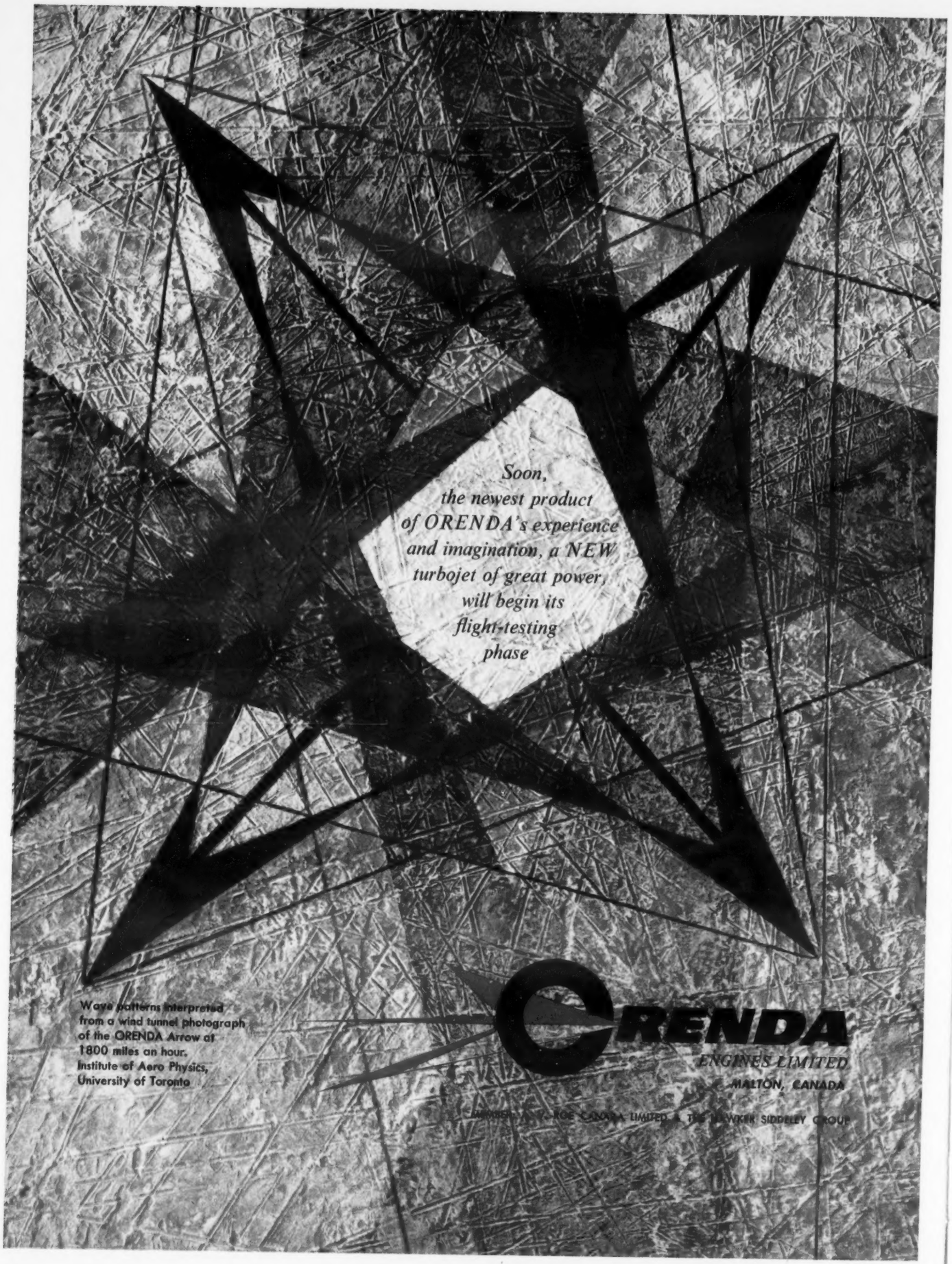
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INTERAVIA

Review of World Aviation

Volume XI | No. 6 | June 1956

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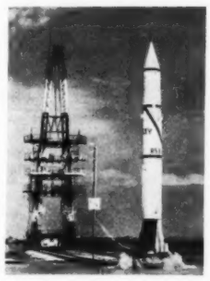

Front Cover:

A Redstone tactical rocket of the U.S. Army on the point of being fired at Huntsville, Alabama. Redstone is the predecessor of a 1,500-mile Intermediate Range Ballistic Missile (IRBM) now under development.

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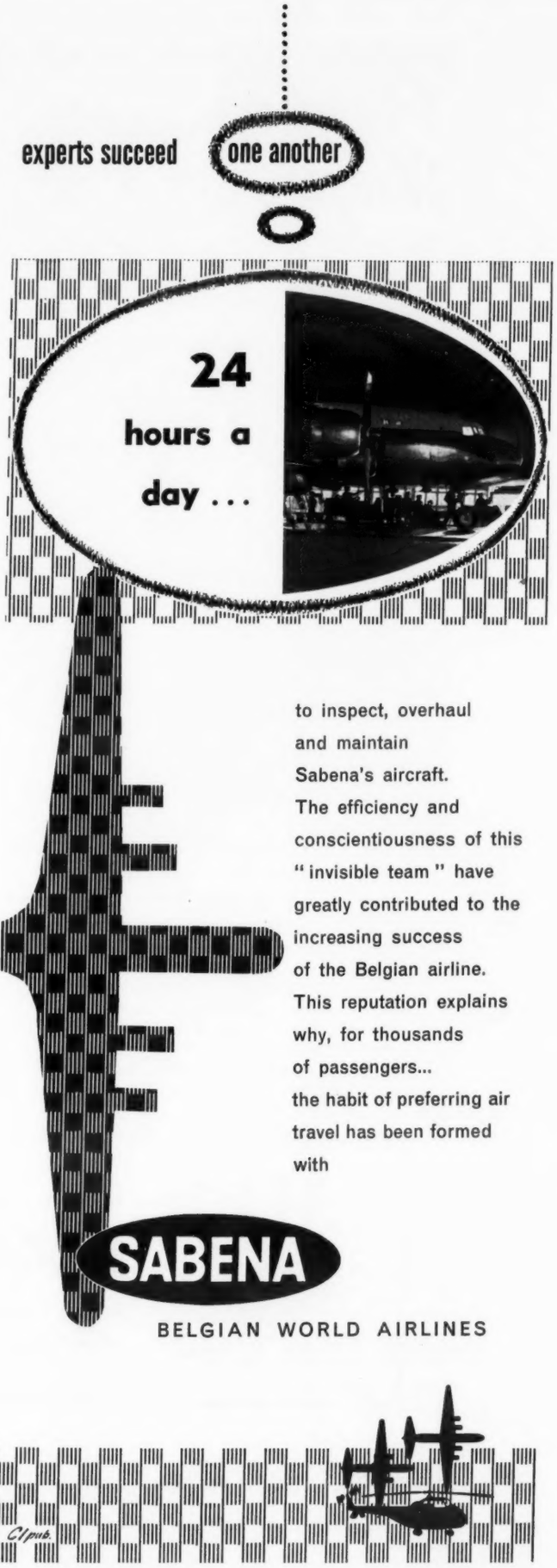

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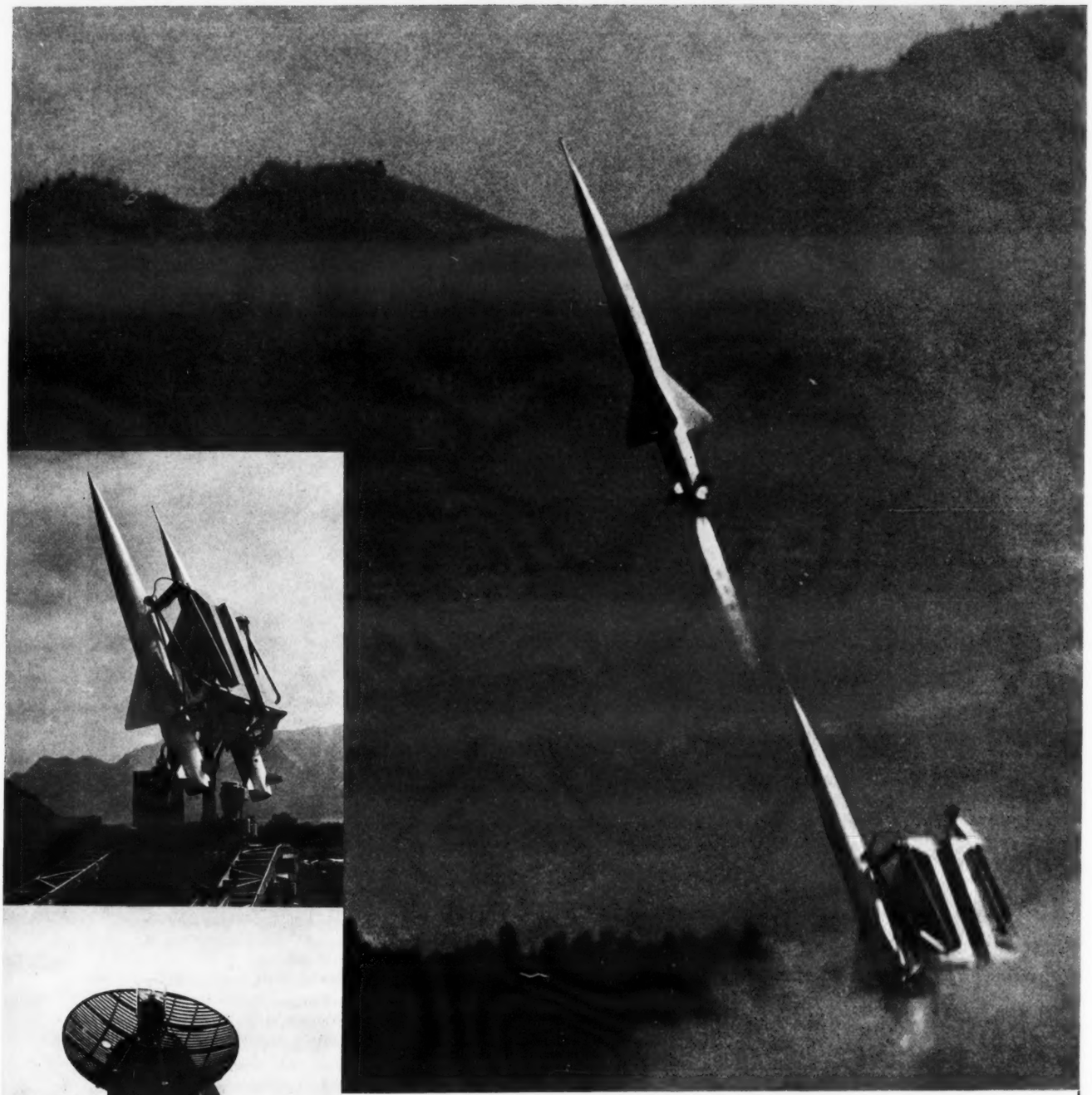

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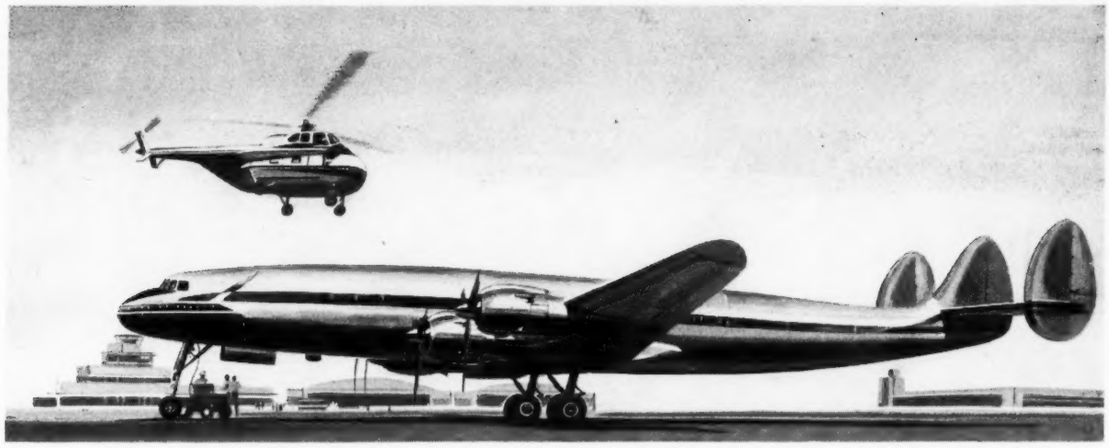

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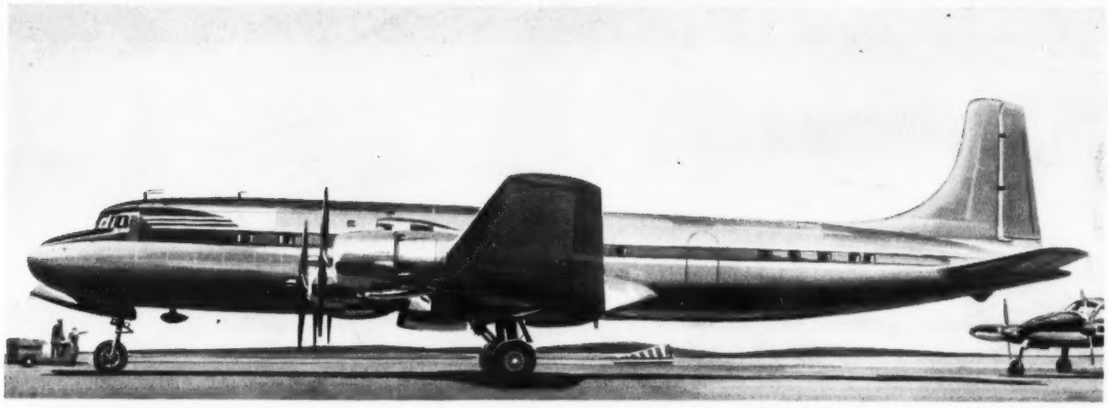

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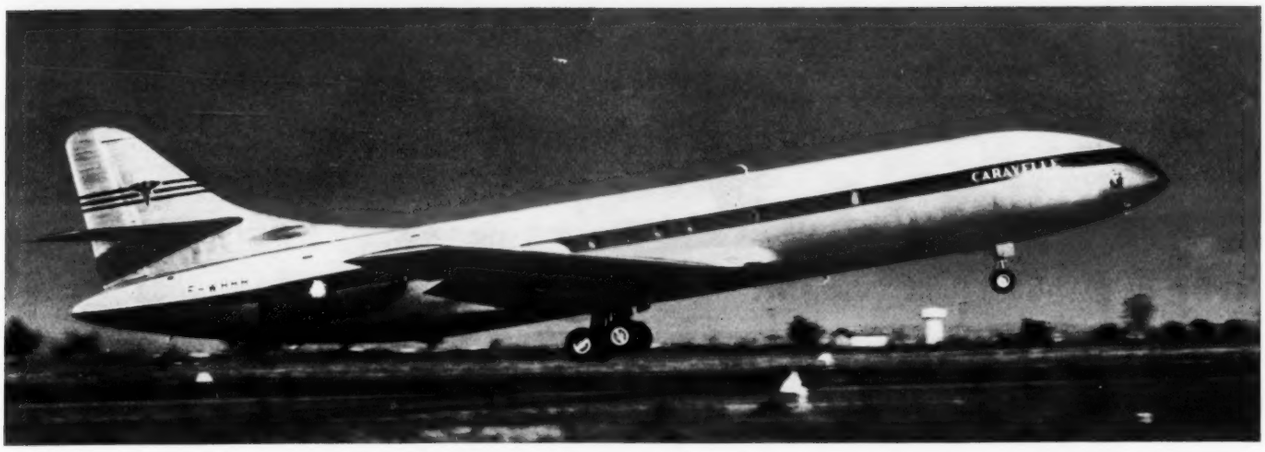

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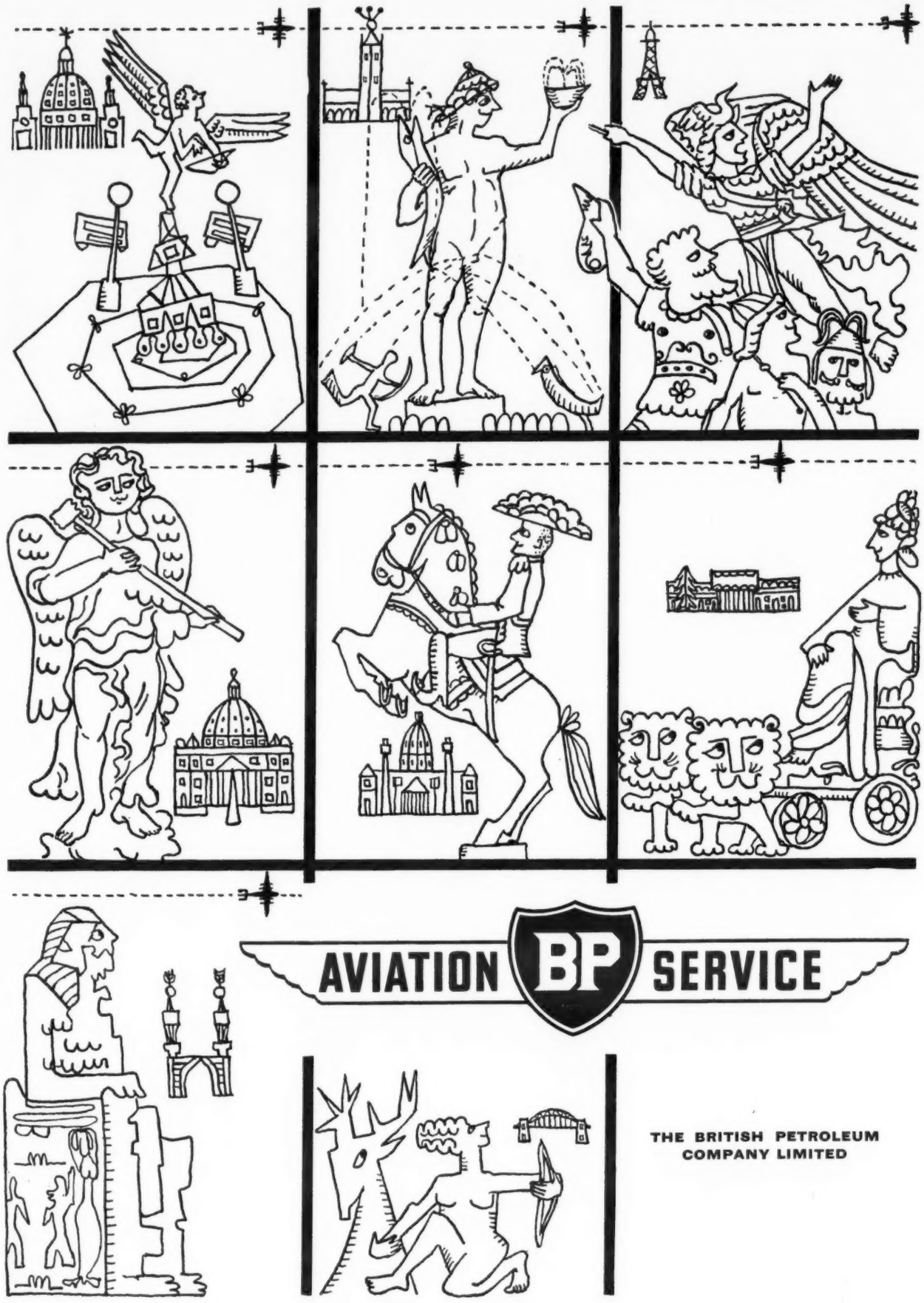
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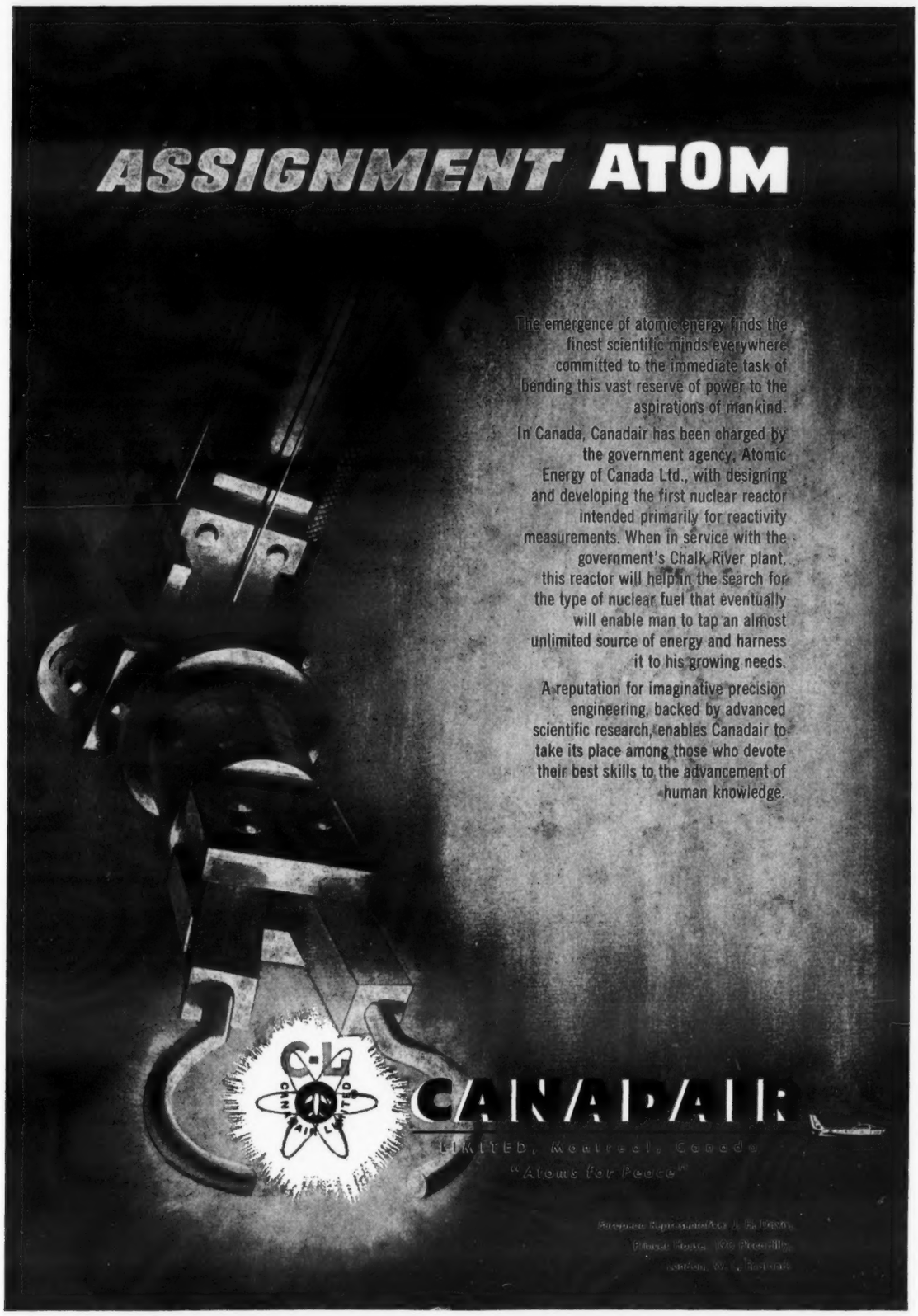
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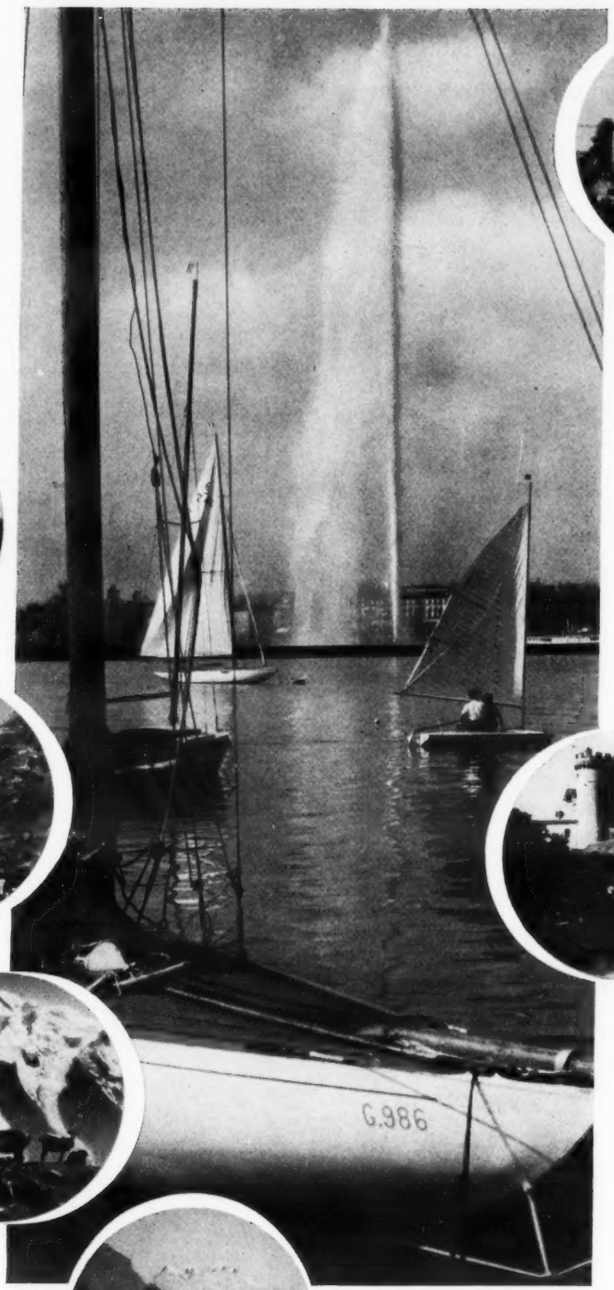

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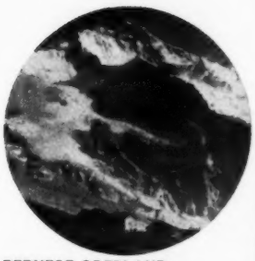

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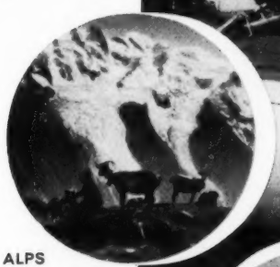

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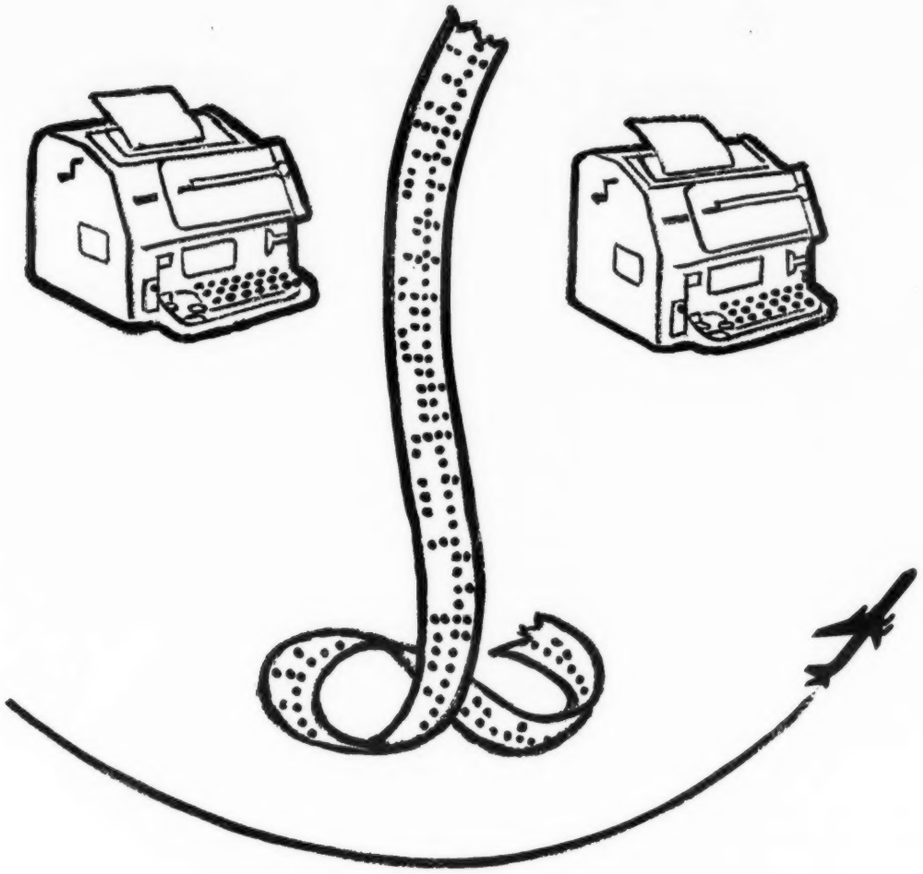

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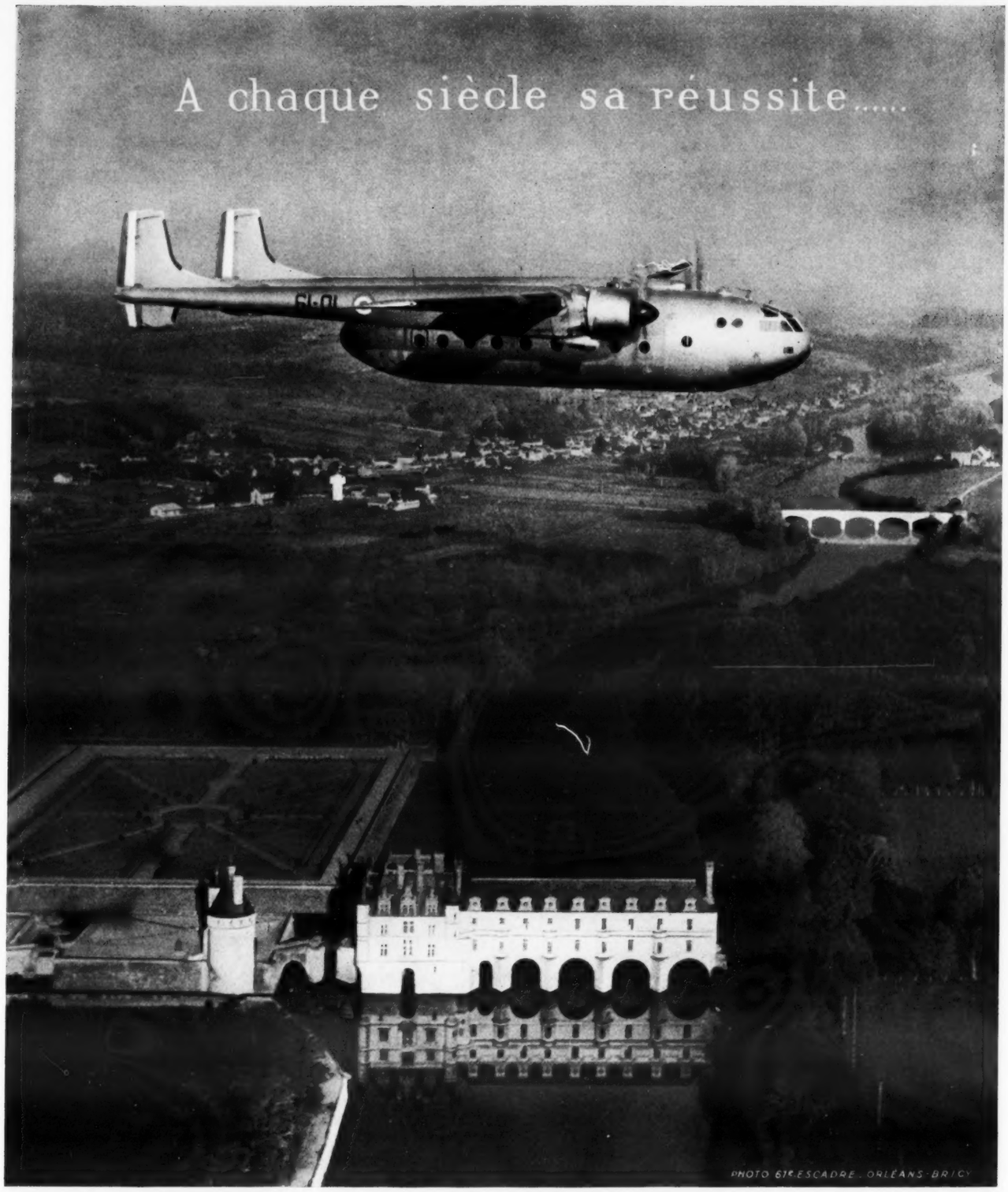

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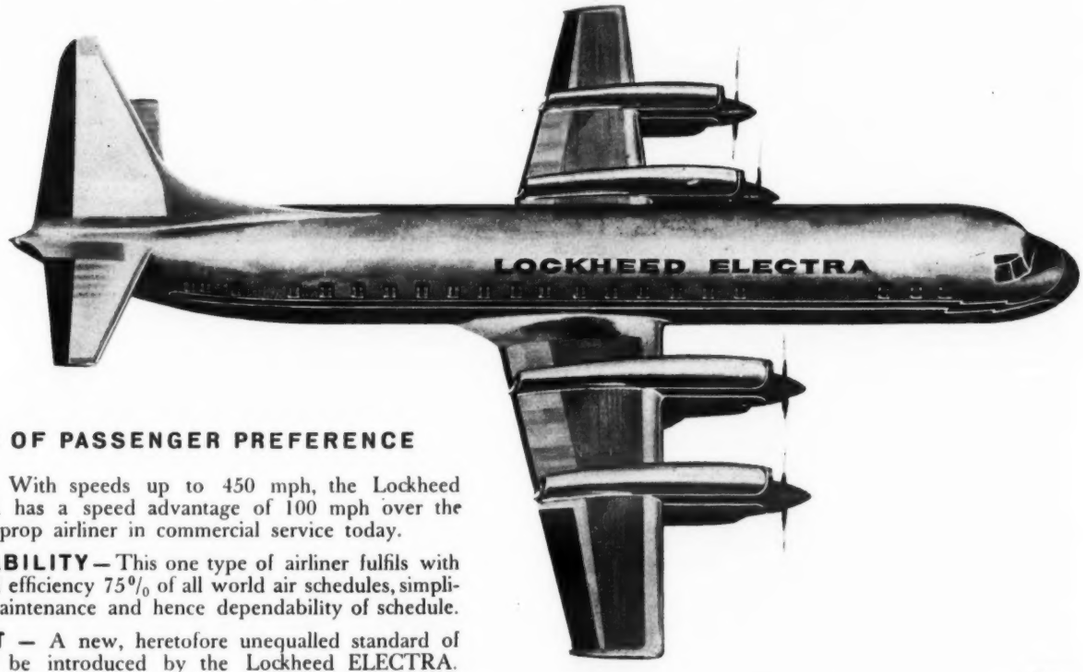

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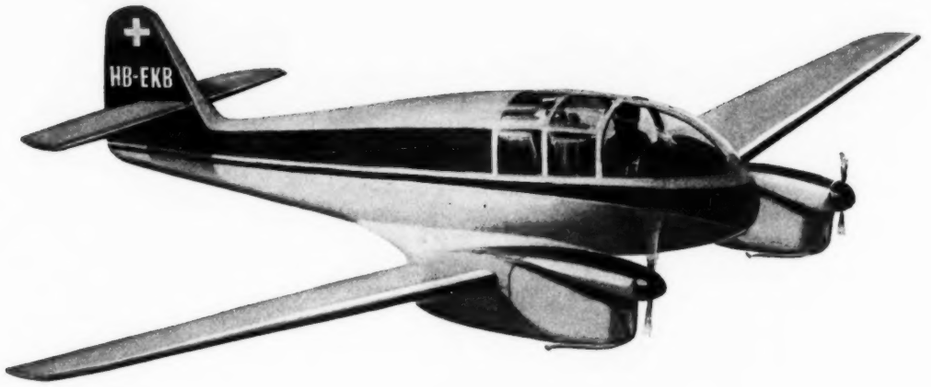

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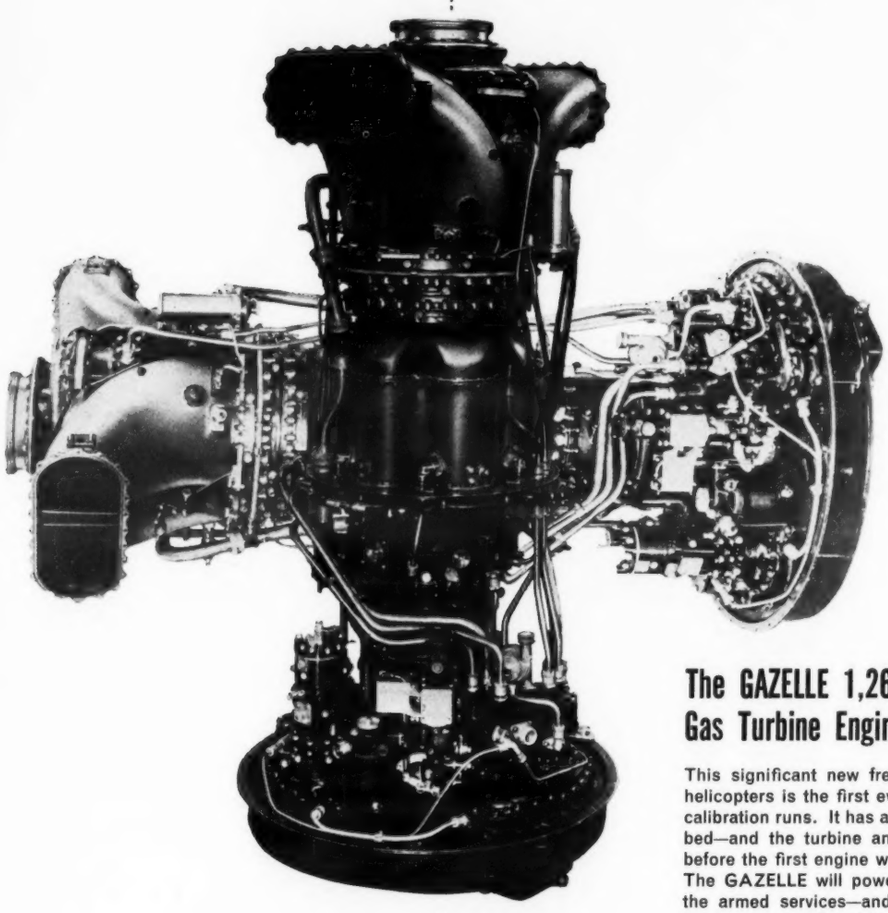

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The GAZELLE will power the twin rotor Bristol 192—designed for the armed services—and the Westland S-58 Wessex helicopter, adopted by the Royal Navy.

The engine embodies a highly efficient small diameter axial compressor and the safe, simple Napier automatic control system. It can be mounted vertically or horizontally, and its application need not be confined to rotary wing aircraft.

Because of the engine's light weight and small size, the installation position in relation to the aircraft's C. of G. is not of vital importance —thus a more flexible disposition of variable cargo and fuel loads is made possible.

The power of the GAZELLE is still being developed. 1,260 s. h. p. and upwards—from the low weight, compact GAZELLE!

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Where drama is out of place

Wind-tunnels, computers, slide rules and test-rigs are all very well, but the only final test of an aeroplane is to fly it.

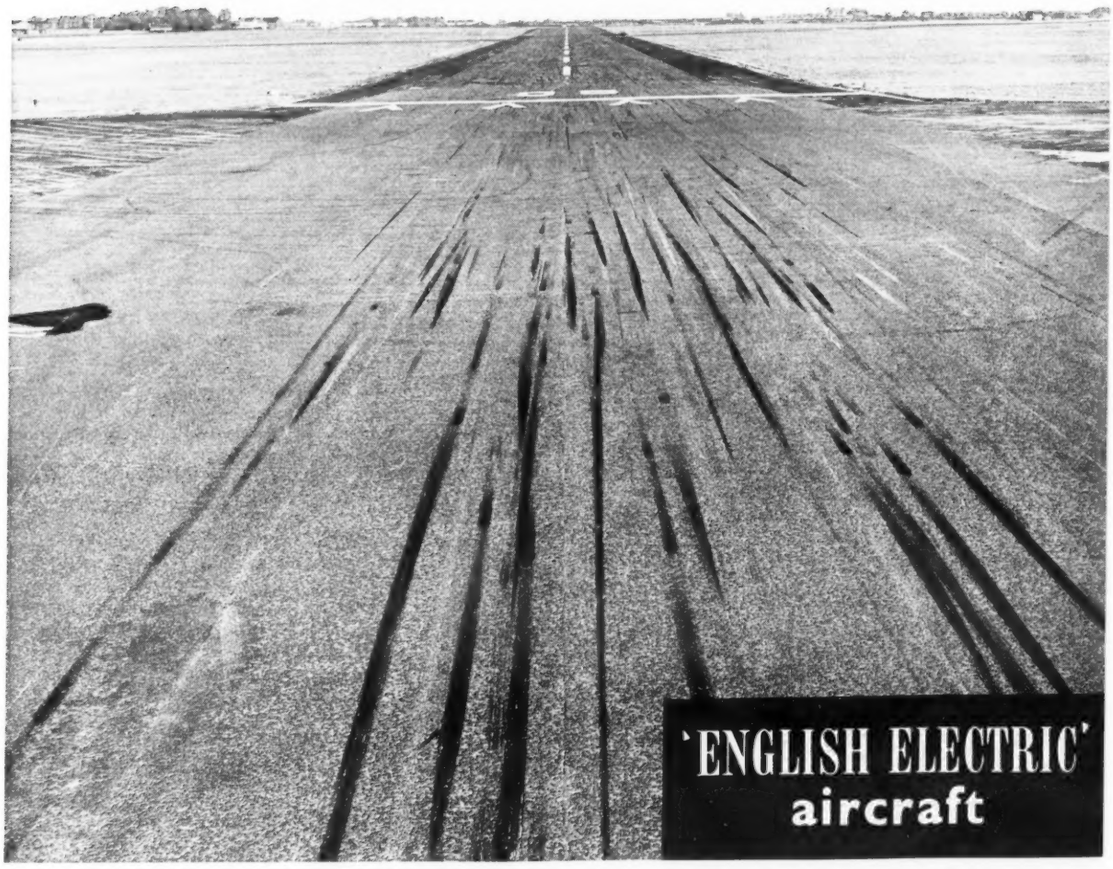
It does not need vast equipment to work out in advance how far, fast and high an aeroplane can be expected to fly, but not even the resources of our research establishment at Warton can precisely predict *how* it will do these things. The final verdict must come from the test pilot who flies it, backed up by the records of the instruments carried on every flight.

Ingeniously compact and versatile though these instruments are, there is never room enough to record at one time all you want to find out. Planning has to begin long before the first flight of the first prototype. Thereafter every single flight has a planned purpose, though there must always be enough flexibility about the plan to let unexpected findings be explored.

But whatever the instruments say, the last word lies with the test pilot. Unless an aeroplane does all it has to do in a way that is acceptable to the human being inside it, it might as well never have been built.

The job of the test pilot is one of great skill, extreme concentration and much less glamour than the films would have us believe. And however lonely his job may seem, he is very much part of a team—the team that has been working so hard and so long and so objectively to see that (in his own words) he has no moments of drama.

Design starts from an attitude of mind



QUEEN'S HOUSE, KINGSWAY, LONDON, W.C.2

Partners in Progress with Marconi's and Napier in The ENGLISH ELECTRIC Group

INTERAVIA

Deadline Notes

No. 6, 1956

THE ARGENTINE GOVERNMENT has authorized Lufthansa to inaugurate an air service between Germany and Buenos Aires, by way of Paris, Dakar, Recife, Rio de Janeiro and Sao Paulo. The provisional authorization will have to be confirmed in a bilateral air agreement between the two countries, according to the Bonn Ministry of Transport.

PROPOSALS TO INTRODUCE THIRD-CLASS trans-Atlantic air fares have been announced by Pan American World Airways and Trans World Airlines. They would be approximately 20% lower than existing tourist class rates. PAA would provide three classes of service corresponding to those in force on ocean liners: first-class, cabin class (the present tourist class) and tourist class. The price of a third-class air ticket from New York to Paris and back would be $458 instead of the present $558. TWA would charge $386 for the same trip, provided the return flight was made within 15 days.

TRANS WORLD AIRLINES and Pan American World Airways have asked the U.S. Civil Aeronautics Board for permission to operate services from the U.S. West Coast to Europe along the Arctic route. According to TWA spokesman, his company is anxious to open this route in order to "compete effectively" with Scandinavian Airlines. He forecast that a total of 60,000 passengers would fly along the Arctic route to Europe in 1958.

SOVIET OFFICIALS have told Pan American World Airways that they would welcome negotiations on the opening of a direct air service to Moscow, according to State Department spokesman Lincoln White. He added that the U.S. Government had not yet been formally approached by the Soviet authorities. White implied that the U.S. Government was prepared to allow Soviet civil airliners to land on American territory. - PAA is already in possession of a CAB certificate of necessity and convenience for a service to Moscow.

THE EAST GERMAN LUFTHANSA is planning to use jet airliners produced in the East German Democratic Republic on long distance routes to China and other countries by 1960, it is reported from East Berlin. The jet aircraft now being developed is said to be a "shoulder-wing model powered with four jet engines and fitted with wing-tip fuel tanks".

THE TOTAL NUMBER OF KILOMETRES flown by Alitalia aircraft in 1955 increased by 12.9% over 1954 to 6,-864,944. The number of passengers carried rose nearly 30% to 81,622; passenger kilometres performed went up by 17.5% to 146,912,548. The company's fleet of four Douglas DC-6Bs and four Convair 340s will be enlarged this spring by two additional DC-6Bs. In the course of 1957 Alitalia will take delivery of two Convair 440 Metropolitans and two Douglas DC-7Cs. Another two DC-7Cs are expected in 1958.

A EUROPEAN CENTRE for flight instrument training work will be established by Lear S.A. Geneva at Geneva-Cointrin Airport at the iniative of the company's General Manager, William P. Lear, Jr. The school will have two specially adapted Link trainers, as well as a single-engined and a twin-engined aircraft equipped with the most up-to-date navigation aids. It will be open to private pilots from all European countries who will be given the opportunity of acquiring an instrument flying licence.

THE INTERNATIONAL AERONAUTICAL FEDERATION (FAI) elected the following officers at its 49th General Assembly in Vienna: President - Dr. Charles Sillevaerts, of Belgium; First Vice President - JacquelineCochran, United States; Vice Presidents - M.C. Kolff, Holland; Jacques Allez, France; Oskar Reichel-Erlenhorst, Austria; Dr. W. Muri, Switzerland; John Foltnann, Denmark; General Napoleone del Duca, Italy; Mustafa Zeren, Turkey; R.H. Mayo, Great Britain; José Juste Iraola, Spain; Dr. Karl-Ferdinand Reuss, Germany.

AIRCRAFT ORDERS are reported by the following companies: Swissair - three additional Convair 440 Metropolitans; Linee Aeree Italiane - six Vickers Viscount 770Ds; Trans Canada Airlines - four Douglas DC-8s powered by Rolls-Royce Conway engines, for delivery in 1961. This is the first order for an American jet airliner powered by Conways.

HUGHES AIRCRAFT CO. has disclosed a carefully guarded secret - it plans to build a jet transport of intercontinental range. Hughes Tool Co., parent company of Hughes Aircraft and 74-percent owner of Trans World Airlines, will build a production plant on a 30,000-acre site in Florida. The plant will "by far transcend in importance, payroll and future development any industrial development now in Florida," official sources state. Hughes Tool plans to build its own airfield at the plant.

* From INTERAVIA's world-wide news service, including INTERAVIA AIR LETTER, the daily international aviation news digest. — No part may be reproduced without written permission.

GRUEN INDUSTRIES INC. is the new name of Gruen Watch Company, Cincinnati. The change reflects the diversification of the company's activities decided on a year ago. With four defence contracts worth $2,239,000 the firm has entered the intercontinental missile and jet instrumentation field. The production programme includes gyro test equipment, aircraft instruments, frequency meters and oscilloscopes.

FORD MOTOR CO. has established a multi-million programme for research, testing, development and production of guided missiles systems. For this purpose a subsidiary called Aeronautronic Systems Inc. is to be formed in California (Los Angeles or San Francisco). An initial research and development investment of $10,000,000 is planned.

H. MANSFIELD HORNER, 52, has been elected Chairman of the Board of Directors of United Aircraft Corporation, in succession to Frederick B. Rentschler, who died on April 25th. New Vice Chairman is Leonard S. Hobbs, 59; new President is William P. Gwinn, 48.

A.C.A.A. TYPE CERTIFICATE has been awarded to the Douglas DC-7C Seven Seas compound-engined commercial transport six weeks before the contract date. Four DC-7Cs were immediately delivered to PAA.

COSTRUZIONI AERONAUTICHE GIOVANNI AGUSTA has received a French Government order for fifty Agusta-Bell 47G2 helicopters. An earlier contract called for 73 helicopters.

THE GUIDONIA WIND TUNNEL is to be reconstructed in agreement with the NATO Advisory Group for Aeronautical Research and Development (AGARD), according to Italian press reports. Cost, 50,000,000 lire. Before and during World War II Guidonia was Italy's major aeronautical research centre.

EIGHTY-FIVE ILYUSHIN IL-14 TRANSPORTS are to be built in the next two years by the East German "VEB-Industriewerk" at Dresden. - From West Berlin it is reported that production of a "twin-jet multi-purpose aircraft" is to start in Central Germany in 1957. Designation of the aircraft is said to be "BB 152" (Baader-Bonnin).

THIRTY-FOUR AIR BASES are to be built for NATO in the territory of the West German Federal Republic to supplement the existing Allied air bases, according to proposals submitted by the West German Defence Ministry. Cost, DM 1,200,000,000. To minimize the danger of bombing or guided missile attack, the bases are to be made as small as possible, with each one probably housing only one squadron. Each base will have one concrete runway, a radar control tower, anti-aircraft defence stations, concealed personnel quarters and hangars.

THE WOOMERA ROCKET RANGE in Australia is being expanded under British-Australian agreement just concluded. Work on additional launching ramps and the installation of new measuring instrumentation has already started.

A NEW HELICOPTER RECORD is reported from Soviet Russia. It was established by a Mi-4 helicopter designed by B. Semskov which attained an average speed of 187.254 km/h over a 500-km closed circuit.

*

WORKSHOP BRIEFS . . .

A supersonic trainer is being developed for the U.S. Air Force by Northrop Aircraft Inc. * Douglas Aircraft has delivered the 3000th AD Skyraider piston-engined attack bomber to the U.S. Navy. * The Napier Oryx N.Or.4 turbine gas generator has accomplished a 150-hour type test at a take-off output of 865 gas horsepower. Flight tests of the Nord 1405 Gerfaut II have so far disclosed exceptionally good behaviour in the transonic and supersonic speed ranges as well as excellent climb performance. * Contractors working on a Short Take-off and Landing (STOL) aircraft type include Doak Aircraft Co., Torrance, Calif., in addition to Fairchild, Ryan, Vertol and Hiller. * The Bristol BE.25 propeller turbine has been named Orion. * A two-seater version of the North American Super Sabre, designated F-100F, has been ordered in quantity. It will be used as a trainer but will be suitable for combat. * Fairey Aviation Co. of Canada is planning demonstrations in Canada this summer of the Ultra Light turbine-powered helicopter developed by Fairey Aviation Co. Ltd. of England. * The first Boeing KC-135 jet-propelled tanker will be ready for flying trials at the end of this summer. * Development contracts for high-power jet engines (in the 25,000-lb.-plus bracket) have been awarded to Allison and General Electric. * General Electric reports that the T-58 propeller turbine (of more than 1,020 s.h.p.) is ready to go into quantity production. * A new jet engine of about 3,080 lbs. static thrust is under development by Générale Aéronautique Marcel Dassault. The first prototype is to be ready for bench tests in September 1956. * More than 550 Fairchild J-44 light jet engines have been produced so far. The engine has recently received a C.A.A. Type Certificate. Thrust, 1,000 lbs. * First mention is made of a Britannia Series 400 turboprop airliner. Compared with the Britannia Series 300, the new version will have a fuselage lengthened by 18 feet as well as a modified tail unit and a thinner wing. Power plant: four Bristol BE.25's. * The Aerfer Sagittario 2 light interceptor started its flying trials on May 19th.

* * *

Faster, Higher, Hotter

BY THEODORE VON KÁRMÁN, PARIS

It would be difficult to find a more qualified person to introduce the present issue on Guided Missiles in 1956 than Professor Theodore von Kármán, *an old friend of* Interavia. *One of the fathers of modern aerodynamics and rocketry, without whom it is generally agreed no rocket aircraft would yet be in existence, Professor von Kármán celebrated his 75th birthday on May 11th.*

*

From a scientific point of view long-range ballistic missiles, earth satellites, and some other vehicles whose feasibility is yet under study, have unique features. Their realization requires extrapolations of theory, experiment and component design far beyond the frontiers of the actually well-known.

Thus, their speed clearly goes beyond the supersonic speed range which has become for us a common everyday matter, and they enter the speed range called "hypersonic".

It is interesting to review the development of aerodynamic theory from the viewpoint of the mathematical abstractions connected with the three distinct ranges of speed.

What we call today "classical" Aerodynamics was in fact based on the idealized concept of an incompressible fluid. It is remarkable how successful this crude approximation proved to be even in the design of airplanes with quite respectable flight speeds. It was only about the end of the thirties that so-called compressibility troubles appeared, made evident by unexpected changes in lift and drag, stability and control. They were found to be caused by the local occurrence of supersonic speeds somewhere on the structure. To be sure, one was not quite unprepared for supersonic problems. The science of exterior ballistics was a kind of semi-theoretical, semi-empirical "Supersonic Aerodynamics". However, the ballistician seldom had serious "transonic" problems comparable to those with which the airplane designer had to struggle. Although specific problems of the "sonic barrier" have not yet been explored in every desirable detail, the aeronautical engineer, in the past fifteen years, has become familiar with "Supersonics" at an astounding pace; a great number of successful manned and unmanned vehicles with supersonic speeds have been designed on a safe scientific basis.

Now we arrive at a new concept: "Hypersonics". As we mentioned above, classical Aerodynamics started out from an idealization of the air as a nearly incompressible fluid. This means in scientific language that the flight speed was assumed to be small in comparison with the velocity of sound (which is equal to about 760 miles per hour at sea level). Now the situation is reversed: in the case of a long range ballistic missile the velocity of sound is small in comparison with the flight speed. What are the consequences?

One remembers in the early history of Aerodynamics—long before the realization of mechanical flight—the battle between the adherents of the sine and of the sine-square laws of air resistance. Newton concluded from the concept of the deflection of individual air molecules by a moving surface that the force acting on a inclined surface has to be proportional to the square of the angle of inclination of the surface. His successors found that on the basis of this law there was little hope of making a practical flying machine. Experimental facts have shown that the sine law was correct; it was generally used as an empirical law. Finally, harmony between theory and facts was achieved by a correct understanding of the phenomena involved. The sine law proved itself applicable to both the subsonic and the supersonic ranges.

Now we find that for the hypersonic range (i. e., for supersonic motion with very large Mach number) Newton's law is rehabilitated: it furnishes in this range correct values for the forces acting on bodies.

The main characteristic of hypersonic flight is, however, the occurrence of terrifically elevated temperatures. We learned in "Aerothermodynamics" the concept of the stagnation temperature, i. e., the temperature produced by deceleration of the air particles relative to a moving surface to a zero value, for example by a shock or also by friction[1].

I always found "aerodynamic heating" one of the attractive problems of Aerothermodynamics. Galileo Galilei mentions in one of his dialogs that assertedly some Babylonians used to cook their eggs by whirling them on a string with high speed. He correctly remarks that he is not willing to accept the theory that the friction of the air would heat the eggs. He is more inclined to believe that if the eggs were already hot, they would be cooled by the air. It is easy to show that Galileo was right. The relative speed between the eggs and the air would have to be several times sound velocity in order to obtain the desired heating effect. However, if a vehicle moves with a Mach number of 3 or 4, the heating effect becomes a serious problem, and for a vehicle entering the dense atmosphere with a high Mach number the problem of cooling is evidently quite critical.

In such cases—by the way—Aerothermodynamics is not sufficient to predict the phenomena. Because of dissociation of the air at high temperatures, Aerothermochemistry takes the place of Aerothermodynamics. Furthermore, at high altitudes where the vehicle moves through a highly rarified medium, it becomes questionable whether we can apply the dynamics of continuous gases at all; we may have to replace fluid dynamics by the kinetic theory of molecules and, if the medium contains charged particles, we touch the frontiers of a science which recently has been baptized as "Magnetogasdynamics".

The reader will find in the technical literature of tomorrow many papers dealing with problems connected with flight outside the atmosphere proper, such as problems created by the presence of meteoric dust, by the effects of solar and cosmic radiations. I assume some papers will deal with the problems of guidance, control and navigation in the space between, say 20 and 400 miles above the earth.

The purely ballistic missile circumvents the problem of navigation by starting the precalculated trajectory of the final stage with exactly defined initial conditions. The accuracy of hitting the target depends then essentially on how exactly these initial conditions are met and how exactly we know what happens in space.

I will leave to the authors who have contributed to this interesting issue the task of discussing when, where and by whom, and with what success the first intercontinental ballistic missile will be built and tested, and what the outcome will be.—One thing seems to me to be beyond doubt. That is flight at such elevated speeds, and in such high regions of the atmosphere, involves problems which should attract the attention and devotion of the highest class of scientific minds.

Perhaps this is the most important element from the point of view of the progress of the human mind. Who remembers the men who directed England's political, economical and military affairs at the time when Newton found the fundamental laws of gravitation which hold together the planets and keep them going around the sun along their prescribed trajectories?

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[1] The ratio of the stagnation temperature measured on an absolute scale (in "Kelvins") is equal to unity plus one fifth of the square of the Mach number. If the Mach number is very small, $\frac{1}{5} M^2$ is a small correction to unity. If, however, M^2 is a large number, $\frac{M^2}{5}$ is large relative to unity. Assume for example the ambient temperature to be equal to 220° K. Then for a case of a vehicle moving with a Mach number of twenty, $1 + \frac{M^2}{5}$ is equal to 81, and the stagnation temperature is of the order of 17,000° K, a temperature far beyond those occurring in any technical device, with the exception of nuclear bombs.

Guided missiles

The Intercontinental Ballistic Missile will Change Tactics but not Strategy

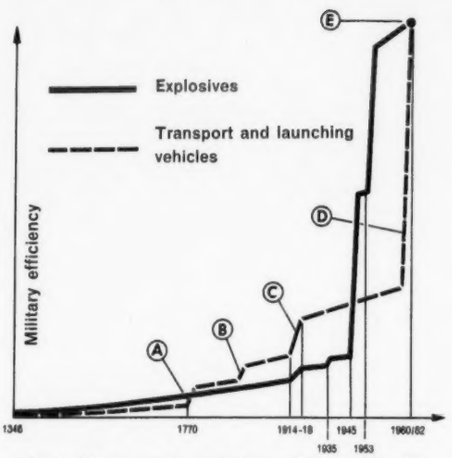
BY INTERAVIA STUDY GROUP

The "wedding" is expected to take place between 1960 and 1962. Then the union between the intercontinental missile and the thermonuclear explosive will give birth to the *supreme weapon*. If the evolution of explosives and of the various weapons which have carried or launched them could be represented graphically, it would be seen that this half of the twentieth century has been fertile in sudden transformations (*fig. 1*).

Between 1346 and 1945 the destructive power of explosives progressed in step with molecular chemistry. But this improvment in efficacy is slight compared with the level reached in 1945 with the atomic explosive. Eight years later the thermonuclear explosive catapulted this destructive power to new heights measured in megatons.

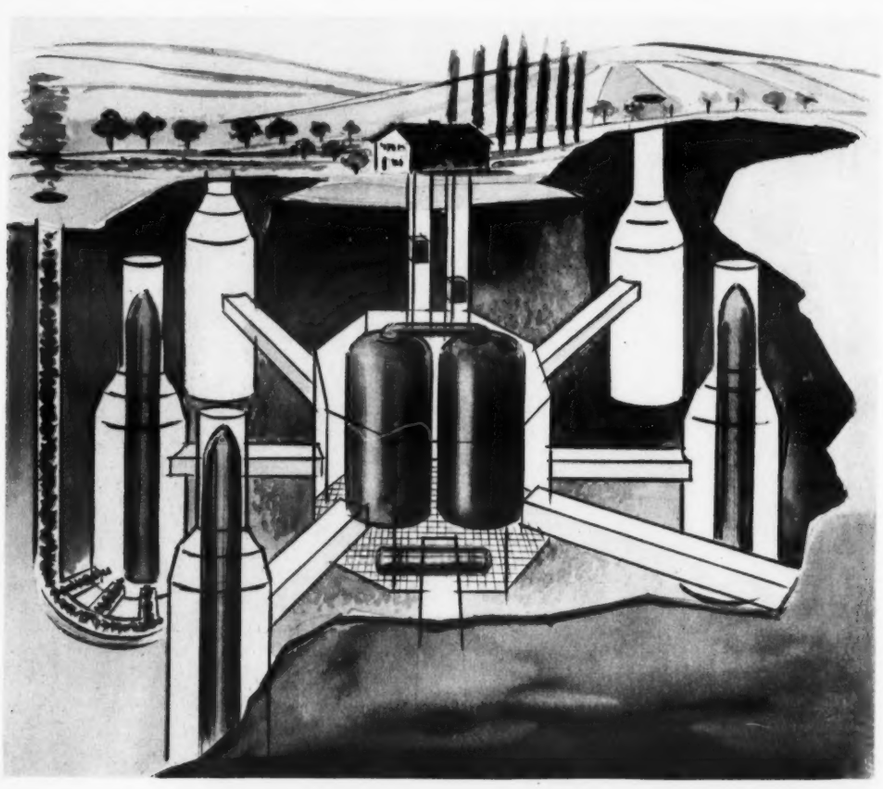
From the *bombardes* of the Battle of Crécy in the 14th Century to General de Gribeauval's cannon of the 18th, constant improvements were made in cannon. Then the iron-clad, aircraft, tank and "Big Bertha" all marked further stages in the increasing efficiency of the means of transporting or launching the explosive. In 1945, however, the ways parted. The projectile jumped from the 10,000-lb. TNT "block buster" to the Hiroshima atomic bomb equivalent to 20,000 tons, while the B-50 of the atomic age remained very similar to the B-29 of the pre-atomic era. Although today it has conquered the sound barrier and is on the way to twice the speed of sound, the bomber has not yet caught up with the status attained by the nuclear explosive since the American and Russian thermonuclear explosions. But the intercontinental ballistic missile, almost invulnerable on its launching sites and at present completely invulnerable when on its trajectory, attracted as it is by the heat of cities and capable of diving onto them at speeds twenty times higher than that of sound, will raise the level of the delivery weapon to that of the nuclear explosive. The "couple" will form an awesome combination.

Will there be a revolution in the relationship of forces and in their possible conditions of employment, that is in matters of strategy? It is generally maintained that there will, but the question requires closer examination.



Historical development of explosives and their vehicles (diagram I): Whereas the efficiency of explosives and their vehicles developed more or less in step for six hundred years, the two world wars initially saw an incomparably faster development in the vehicle... until the atomic bomb radically reversed the situation. A – classification of artillery according to operational applications; B – transition to breech-loading cannon; C – introduction of aircraft and tanks; D – intercontinental ballistic missiles; E – "absolute" weapons system.

Today, the essential instrument of a world war would be the aircraft carrying atomic projectiles, and an aggressor's first object would be to destroy, in a surprise attack, his victim's strategic squadrons so as to escape the effects of the reprisals they would otherwise take. The push-button warfare, of which there was already talk in the United States when Thomas K. Finletter published his famous "Survival in the Air Age" is actually an old reality. By pushing the button to set off his initial offensive, the attacker would automatically operate the button governing his opponent's retaliation. The only problem for him would be to make sure that the second button would be without effect because no reprisal units had survived the initial attack. The same will apply when the robot missile has replaced the piloted aircraft. It is difficult to imagine a prolonged exchange of thermonuclear missiles causing increasing destruction on either side and having no other effect than to wipe the two belligerents off the map. Rationally speak-



If the installations required for launching intercontinental ballistic missiles were built underground for protection, they might be arranged as illustrated here. All common resources (propellants, guidance equipment, control, stocks of missiles) would be grouped together as close as possible to the maximum number of launching points. The fact of being deeply buried would ensure safety, and it would be less dangerous to concentrate a substantial number of aero-nuclear reprisal weapons within a small area.

ing, recourse to the supreme weapon would seem to be possible only if one or both of the following conditions are met:

— the enemy's missile launching bases could be destroyed, and the country deprived of the ability to retaliate for a long period;

— the aggressor had anti-missile defence missiles which practical tests had proved to be infallible. In this case it would matter little to him whether or not he destroyed his victim's missiles on their launching bases, since he would be certain of being able to intercept them en route. As General Fuller predicted immediately after World War II, we should have arrived at battles between robot missiles which would briefly light up the stratosphere.

Despite the efforts already being made to produce a means of defence against missiles, to develop an anti-missile missile, the offensive will probably be markedly superior to the defence. The more so, since the experts are at the same time working on means of protecting their intercontinental rockets, providing them —like the shark with its sucking fish—with small missiles capable of destroying the defence missiles, i. e., with "anti-anti-missile" missiles. As everyone knows, the battle between bullet and armour plate is by no means over, and today and probably tomorrow too—if not even later—the offensive still has definite advantages over the defence.

Hence, whether we are dealing with intercontinental missiles or with long-range aircraft, general strategy remains unchanged. The attacker must seek to destroy the means of defence by surprising them at their bases, unless he is sure of being able to stop them in the air. The introduction of long-range missiles would merely modify certain tactical aspects of this general strategy which has been rendered virtually unchangeable by the existence of nuclear explosives.

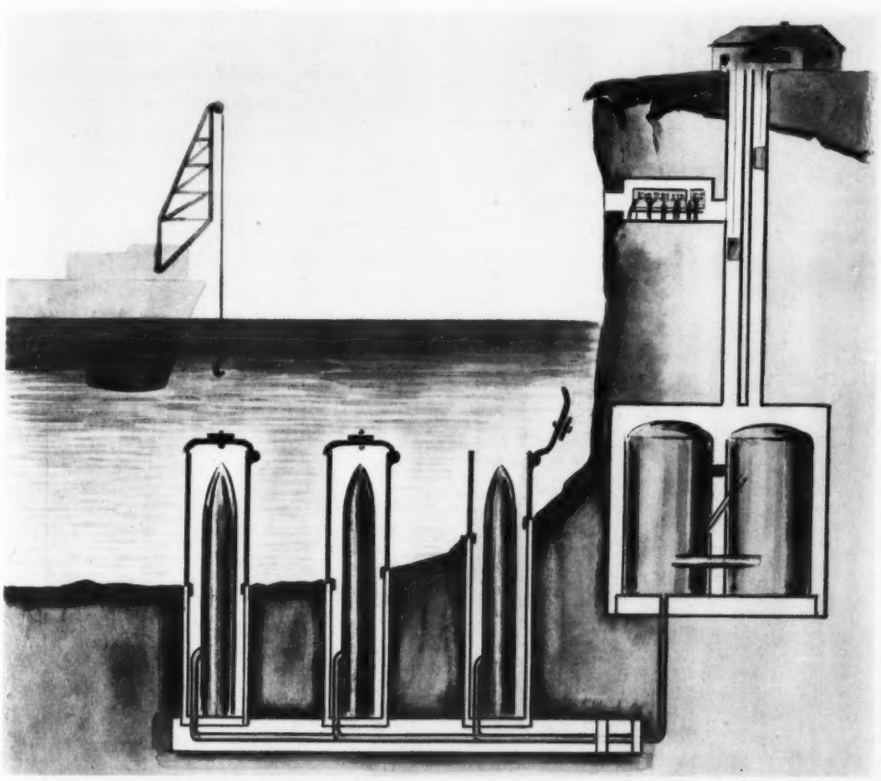
Increasing the number of launching bases

In theory, the replacement of piloted aircraft by missiles and of tangential take-off by vertical launching should do away with the necessity for present-day air bases with their large concentrations of men and technical facilities. The requirements of training, the necessity of servicing the equipment used in preparing men for the role of combatants in action, the distance required for take-off and landing have gradually led to the present concentration of specialists and buildings around a runway as long as possible situated in an open space with few obstructions. The size of these bases has been dictated by conditions of life in peacetime and by the effort to economize in personnel and installations rather than by concern for the vulnerability of such an establishment. The advent of the missile enables this concept to be modified. The runway disappears, and the launching base is transformed from an area site to a virtual "point" site. Training can be limited to a small nucleus of specialists, since there is practically no wear and tear on the missiles, and hence technical maintenance can be virtually eliminated. In theory, the number of launching bases could be increased, if not to infinity, at least to match the number of missiles available. There would be two important consequences:

— there would be a race between the number of launching bases on the one hand and the number of missiles set aside to destroy them on the other. Each side would endeavour to outdo the other and thus render aggression impracticable;

— this race would exhaust the economic resources of both sides during the period of enforced co-existence, and lead, in the event of war, not only to the destruction of reprisal weapons but also to the total destruction of the country attacked, since this country would have studded its territory with missile launching bases, and to attack all these would amount to wiping out the country itself. The conflict would thus end in the large-scale extermination of the victim, or even of both belligerents if the aggressor's calculations did not quite work out in practice. In the age of the intercontinental missile even more than in that of the strategic bomber, this strategy thus seems to involve too many risks for it to be employed. It is obvious, however, that if there were not some kind of balance between the reprisal forces on both sides, *the one with superior strength would have at his disposal an exceptional instrument of intimidation. Simply by issuing an ultimatum he could impose his will on the world just as brazenly as if he had previously removed all adversaries by force.*

But would it be possible to increase the number of launching bases to this extent? Judging by what has so far been written on the supreme weapon, the intercontinental ballistic missile is not a simple V2, but a gigantic machine which appears to require tremendous static installations, preferably underground. We thus revert to a concentration of facilities similar to that which characterizes today's air bases, with the difference that it is no longer impossible to bury them underground. Financial considerations will doubtless limit the extent to which launching installations can be split up, and military experts and economists will be obliged to agree on some compromise, that both meets the threat and is within the taxpayer's means, between bases studded all over the territory and the present concentrations around runways.

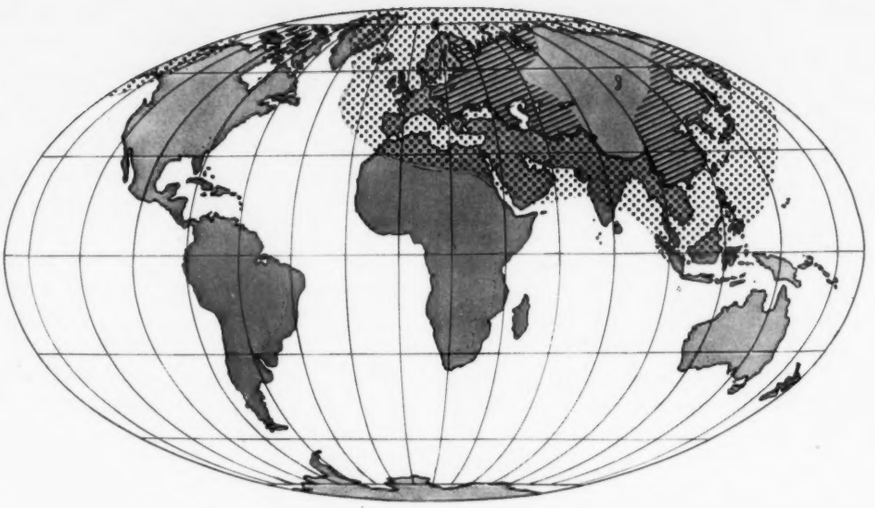


It is also possible to envisage under-water installations. They would have the disadvantage of increased complexity but might have advantages in the matter of secrecy, protection and initial guidance. Launching tests would have been carried out long before to demonstrate the value of water as a "stabilizer" immediately after launching.

Surprise

Is surprise easier to obtain with long-range missiles as an essential means of aggression than with piloted aircraft? Yes, in that the speed at which intercontinental missiles travel is much higher than that of strategic bombers. If the speed were twenty times as high, the time needed for an offensive from one continent to another would no longer be counted in hours (less than ten hours for example) but in minutes (less than twenty minutes). Once the missiles were under way total surprise would be possible, and even if total surprise were not obtained the warning period would be too short to be utilizable by the defence. There remains the field of preparation for an offensive. It is here that in future the conditions of surprise will be assembled.

If the aggressor had made sure of a good technical lead over his prospective victim and if he used missiles to attack a reprisal force based on squadrons of piloted bombers, he would have the advantage of numbers and of dispersion. Having only a limited number of targets—the adversary's air bases—to attack, he could mobilize and launch against them sufficient missiles to destroy them without losing the advantage of surprise. On the other, if he is not technically superior and if both sides have intercontinental missiles dispersed over the maximum practical number of launching bases, the attacker will have to mobilize tremendous forces to achieve his object. In this case it might not be possible to reach total surprise in view of the scale of the offensive. But is surprise still really necessary? Since the launching bases for long-range missiles can be buried underground, they will of necessity be static. They would escape destruction not by movement, like the aircraft squadrons, but because of the protection afforded them by a hundred or more feet of rock, concrete and earth. Surprise will not be as vital as it is today when it would be essential to take the air units by surprise on their bases before they could take off.



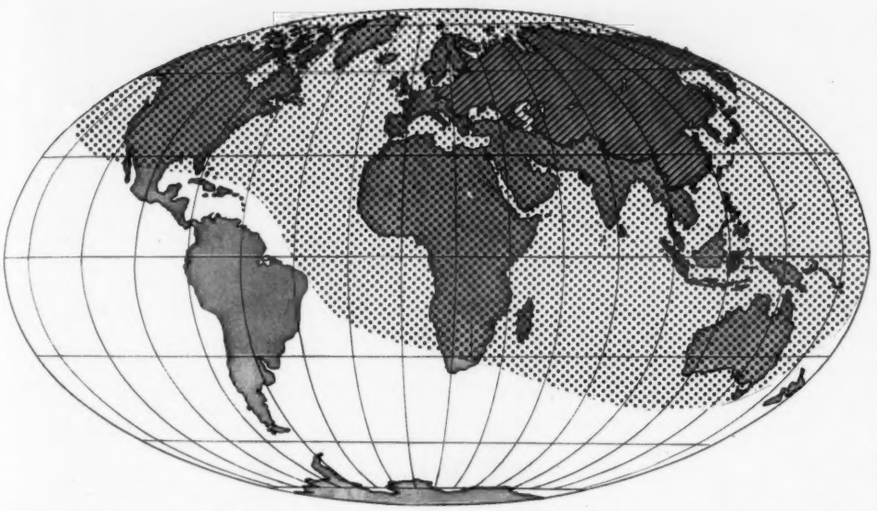
First hypothesis: If Russia were the first country to produce atomic missiles of intermediate range (up to 1,500 miles), the advanced bases of the West's reprisal forces – in Europe and Asia – would be within their range (light dotted area), but not the main body of the U.S. Air Force stationed in the continental United States. – *Second hypothesis:* If the United States had intermediate range missiles, the whole of European Russia, part of Russian Asia and wide areas of China would lie within the danger zone (dark striped area).

Invulnerability on the ground?

If a whole plant has to be set up near the launching base in order to feed the intercontinental ballistic missile's multi-stage rocket motor, it will be necessary to dig into the mountains or bury the installations deep in the ground. This would make it very difficult, if not impossible, for an enemy to destroy the missiles at their bases. Admittedly, missiles with hydrogen warheads designed to explode in depth would churn up millions of cubic feet of earth and might destroy even deeply buried installations. But the question of accuracy of aim arises. A problem of final guidance is encountered, the solution of which is at present very difficult to envisage. A system of protection by means of widely dispersed underground bases would place a would-be aggressor in a position where he could resort to force only if he were convinced of possessing virtually infallible anti-missile missiles. Such a prospect is a very distant one.

Recently General Carl Spaatz, using a classification system which appears to be fairly generally accepted, spoke of an intermediate missile with a range of 1,200 to 1,500 miles and an "absolute" missile with a range of 4,000 to 5,000 miles. The American press has also announced that the Russians have already launched an intermediate range missile in Siberia. It was not stated whether this was an air-breathing device like the *Navaho* or the *Snark,* or a ballistic missile, which would travel at Mach 15 or 20. Despite the advantages of missiles with constant propulsion (early availability, range, precision), their advantages over the piloted bomber are not of a kind to modify strategic conditions to the same extent as the medium or long range ballistic missile.

Today's early warning radar systems provide adequate warning of the approach of long-range bombers (piloted or otherwise), but are powerless against space rockets. Picture shows the erection of the steel platform for an early warning radar in the U.S. – Canadian Distant Early Warning Line in northern Alaska.



Third and fourth hypotheses: Intercontinental ballistic missiles with atomic warheads (range roughly 5,000 miles) – whichever side possessed them – could be launched against all strategically important parts of the world. However, a would-be aggressor could make use of them only if he were certain of being able to destroy his adversary's reprisal forces on their bases or intercept them en route.

Light dotted area = range of Soviet intercontinental missiles (with bases throughout the territories of the Eastern *bloc*).

Dark striped area = range of American intercontinental missiles (with bases in Alaska and northern Canada).

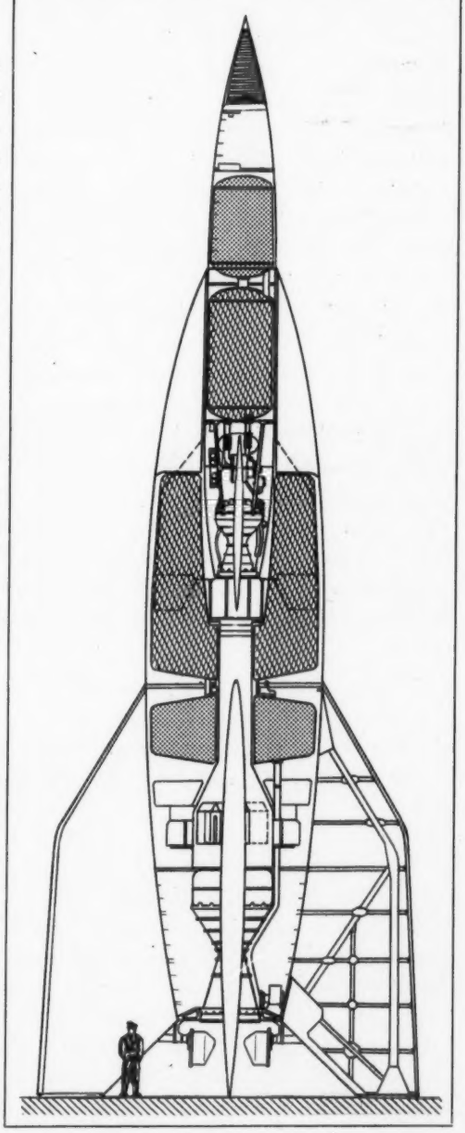
German project for a long-range missile

Towards the end of World War II the German Army Ordnance at Peenemünde projected a two-stage long-range missile (designation A 9/A 10) which was to have a range of more than 3,000 miles and would thus have approached the present concept of the intercontinental ballistic weapon. After the war these plans came into Allied hands; Russian designers are believed to have used them as the basis of a Soviet missile developed during the past few years.

Some technical data of the A 9/A 10 are given below:

	1st stage (A 10)	2nd stage (A 9)
Length	65.5 ft.	46 ft.
Diameter	13.5 ft.	5.4 ft.
Span of fins	29.5 ft.	—
Payload	35,850 lbs.	8,200 lbs.
Weight incl. propellant	152,240 lbs.	35,850 lbs.
Total launching weight	188,090 lbs.	
Thrust	441,000 lbs.	56,000 lbs.
Duration	50 secs.	90 secs.
Max. speed (at burn-out)	2,660 m.p.h.	6,260 m.p.h.
Max. height (flat trajectory)	80,000 ft.	100 miles

Another long-range two-stage missile with a total launching weight of roughly 100 tons was also planned.



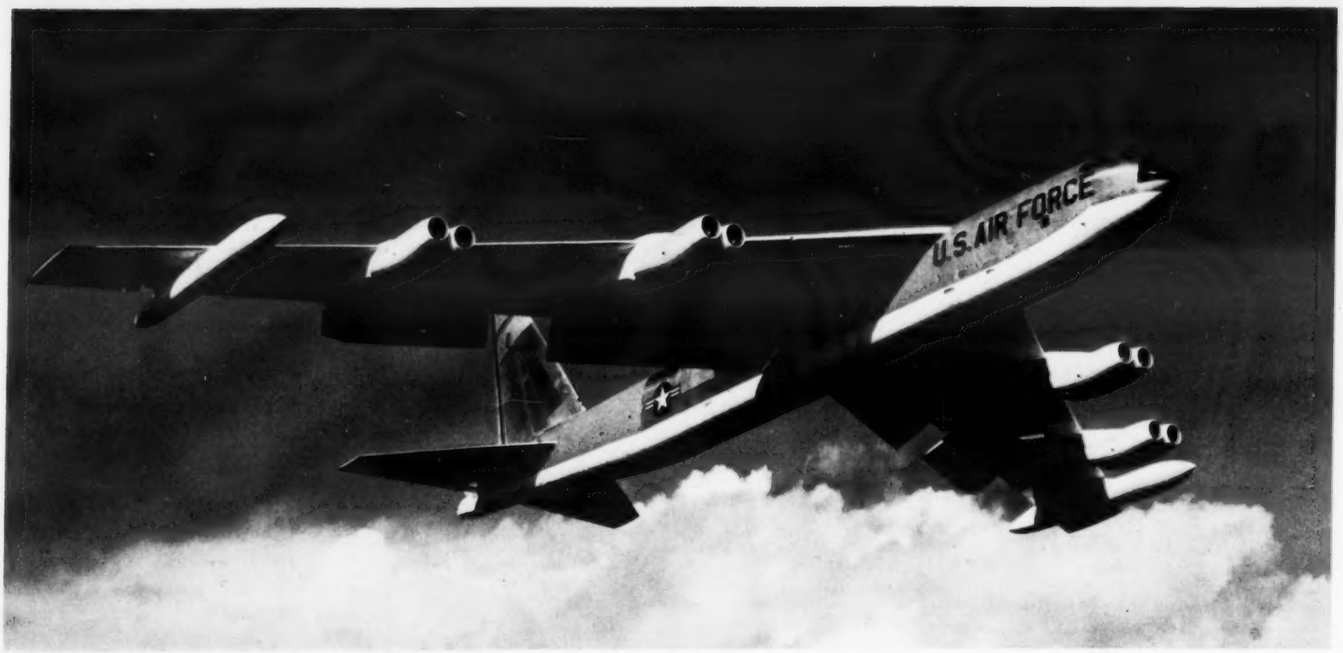
A few weeks ago the U.S. Joint Chiefs of Staff met in Puerto Rico to discuss, among other things, how advanced the Russians really are in the matter of long-range missiles. The race for the supreme weapon on which the "Biggest Two" are engaged will fall into two stages, they stated (intermediate missiles = I.R.B.M. and intercontinental missiles = I.C.B.M.), and four hypotheses could be envisaged, depending on the side which gains the lead.

First hypothesis

Supposing that Russia is the first to perfect a missile with atomic or thermonuclear warhead, a range of 1,200 or 1,500 miles and adequate precision of aim, over this range, allowing for the radius of destruction of the explosive carried. The Russians would then have a weapon against which there would be no defence and which would keep the whole of Europe under a permanent threat. With China in the Soviet *bloc,* the whole of non-Communist Asia would also be within the range of the Red missiles. Within these regions are situated almost all the Anglo-Saxon air bases outside of U.S. territory. The Alsop brothers have pointed out (in the "New York Herald Tribune") that at present 80% of Strategic Air Command's forces (the B-47s) are dependent on either advanced bases—i.e., airfields in the areas covered by the intermediate missile—or in-flight refuelling. What would be the political and military consequences of such a hypothesis? If the situation it assumes really arose, it would give the Russians important military advantages. They would, however, not be decisive, since the essential core of the West's reprisal forces would still be out of reach. Their importance would lie in the fact that the advanced bases could be destroyed, which would deprive the West of part of its operational resources. Psychologically, the European nations would be in a difficult situation, since they would feel that they were constructing, at great expense, a defensive system that would be virtually useless. Neither radar, nor fighters, nor even present surface-to-air missiles can ward off a hail of ballistic missiles. All that the R.A.F. could do against the V2 was try to destroy its launching ramps. But, while the V2's small explosive charge gave the defence a certain leeway, the position would be quite different with the atomic-warhead ballistic missile. A small number of missiles launched within a few minutes—instead of over a period of months—would suffice.

Second hypothesis

In this case the Western bloc is assumed to have gained the lead. Supposing that, within the next two or three years, the United States had succeeded in developing and producing a respectable number of intermediate missiles with atomic warheads, a range of 1,200 to 1,500 miles and, of course, a great enough accuracy over this range. The West would then have a unique advantage in the purely military field. Whereas in the previous hypothesis the East was not in a position to attack the West's real sources of power, the situation would now



Even after the introduction of intercontinental missiles the United States would probably not dispense with modern piloted long-range bombers. Here the latest Boeing B-52 C *Stratofortress* with large wing tanks; gross weight more than 400,000 lbs.

be reversed. The whole of European Russia, part of Asian Russia and a large portion of China would be within range of the American intermediate missiles. The West would obviously not take military advantage of this situation, since it is committed to a purely defensive policy. But its policies and diplomacy could be greatly strengthened, since a large proportion of the East's military installations and population centres would be undefendable. With the world politically divided as at present, geography would favour the West. But in both cases, under the first or second hypothesis, the winner of the race for the intermediate ballistic missile would gain points but would not obtain an advantage sufficiently decisive to change the relation of forces and hence the face of the world.

The second and last phase, which will end the race, is the possession of the intercontinental ballistic missile with nuclear warhead. The same hypotheses can be put forward.

Third hypothesis

Assuming the Soviet Union succeeded, before the United States, in developing, testing and producing a substantial number of intercontinental missiles with atomic warheads. The whole world would then be within range of their launching ramps. Naturally it could be expected that in addition to these I.C.B.M.s the Kremlin would have a good stock of intermediate missiles (first phase) and that its offensive armament would be complete. It is also assumed that the United States has intermediate missiles and, of course, has strengthened its Strategic Air Command by equipping it with a large number of high performance B-52s and supersonic B-58 *Hustlers*.

Militarily the advantage is with the Russians, but the old weapons—in this case the most advanced piloted bombers—still retain some of their power, and we are back at the conditions of today: the attacker must be sure of being able to destroy them on the ground or in flight. The intercontinental missile would make his task easier but would not guarantee complete success, so that aggression would still be attended by some of its present risks.

Fourth hypothesis

If the United States were the first to prepare a stock of I.C.B.M.s, the instruments of a policy of deterrence would be strengthened. But it is unlikely that any more use would be made of this superiority than was made of the American atomic monopoly between 1946 and 1950. In the matter of discouraging a general attack on the positions still held by the West, the United States would be less dependent on installations outside its own territory. But experience of the first few years of the atomic era shows that a policy of maintaining American forces close to the Iron Curtain is essential, either to prevent recourse to local conflicts, or to win the day if such conflicts do break out.

Paradoxically perhaps, it is more important from the political than from the military point of view for the United States to win the race for the intercontinental missile. Or rather, the West faces the following alternatives: if it is not the first to possess these weapons it is more vulnerable to the threat of force. But even if it possesses them it cannot use them, so that even the political power it might derive from them is weakened.

There remains a fifth hypothesis which would invalidate the conclusions drawn from the first four. Let us imagine that by some technical device, which is still unpredictable even by the most eminent specialists, one side succeeded in developing an anti-missile (and hence anti-aircraft) missile that was almost 100% effective. This would change the whole situation. The necessity of destroying the adversary's launching bases would disappear, and the victim's large cities could be taken as priority targets or at any rate used as stakes in a general ultimatum. The aggressor would be indifferent to the possibility of reprisals, since he could intercept either aircraft or ballistic missiles en route. Then, *and then only,* not the absolute *weapon,* but the absolute *weapons system* would have been found. The first side to possess it would have a lever not just capable of lifting the world but of imposing its laws upon it.

The State of the Art

By Erik Bergaust, Washington, D.C.

A general survey of "The State of the Art" of guided missile development, written by a British expert, appeared in the May, 1955, issue of *Interavia, Review of World Aviation*. Much progress has been made in the field in the past year, but the fact nevertheless remains that the official release of public information on missile development has failed—for obvious security reasons—to keep pace with the advances made by science and industry. Hence, this year's report on "The State of the Art," written by an American trade journalist—concentrates on development trends, particularly rocket power plant research and production trends, rather than on individual missiles. However, all available missile information is again provided in tabulated form. The present article confines itself to the two principal guided missiles protagonists—the United States and the Soviet Union. The much more limited British missiles programme forms the subject of a separate article; on the other hand, little new information has been issued about the guided missile activities of other European countries, such as France, Italy, Sweden and Switzerland, and the available data are therefore also grouped in the table forming part of the present article. - Ed. -

Development trends in guided missile science in the U.S.A. during the last twelve months have been highlighted by advancement in guidance design and engineering, and progress in the propellant fields. Many new names, such as *Titan, Tartar, Thor* and others, have been identified with weapons systems now included in the projected United States missile arsenal. More money has been allocated for missile development than ever before; more people and larger facilities are devoted to missile research and production.

Guided and non-guided missiles and rockets in the United States today include these basic categories:

1) surface-to-surface (SSM)
2) surface-to-air (SAM)
3) air-to-surface (ASM)
4) air-to-air (AAM)
5) air-to-underwater (AUM)
6) underwater-to-air (UAM)
7) underwater-to-surface (USM)
8) underwater-to-underwater (UUM)

Their speeds now extend from subsonic to supersonic and they have varying range capabilities and guidance systems.

The Joint Chiefs of Straff made it clear in 1955 that the United States must do more than to maintain its strategic deterrent; it must also establish a tactical deterrent. It must be able to punish local aggressions with such speed and force that the enemy will call a halt before he has an opportunity to even consider large scale aggression. This is the concept of the so-called double deterrent to wars of tomorrow. It is based on an extensive use of guided missiles.

The aircraft industry has made great progress in missiles during the last few years, but scientists are still fighting the basic engineering problems—the biggest of them all being how to more nearly approach perfect guidance systems.

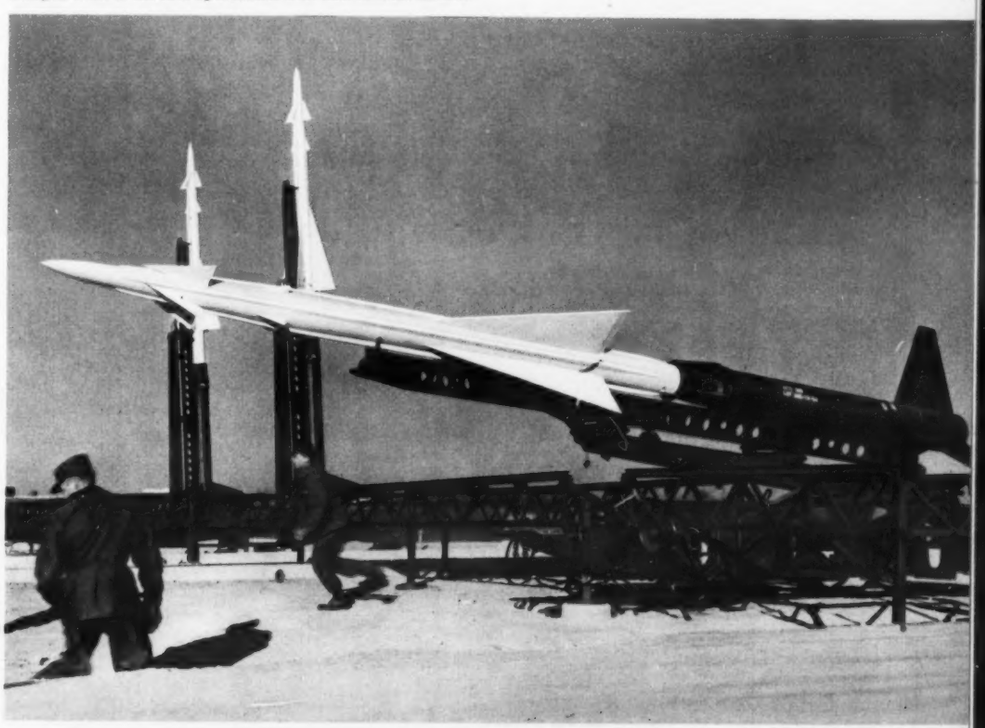
*

Guidance and Control

The principles of the main guidance and control systems were outlined in last year's "State of the Art" survey published in the May 1955 issue of *Interavia Review*. Briefly, guidance systems are divided into two general categories, those used against moving targets and those used against fixed targets. Guidance systems are further broken down into a number of basic types. Systems most useful against moving targets are the *beam rider* (sometimes called *beam timer*), *homing* and *command* systems.

Guidance methods have been improved considerably during the last twelve months, and many of them have been developed to a reliability level that permits system mass production. Improvement in firing control of surface-to-air missiles, such as the U.S. Army's standard anti-aircraft weapon, the *Nike,* is perhaps most significant of recent advancements.

Douglas *Nike* is the first operational U.S. anti-aircraft missile.



Guided missiles

Development of the so-called *Missile Master* system was started in 1945. For two years now this system has been in experimental operation at Fort Meade, Maryland; shortly Missile Master systems will be installed at all key anti-aircraft sites in the United States. Each system operates independently, and can also operate in conjunction with units of the Air Force "Semi-Automatic Ground Environment" area defense system, better known as SAGE.

Missile Master is a complete electronic system for the coordination and direction of a large number of surface-to-air missile batteries. The system collects information on the location of aircraft and their identity, presents this information on electronic displays, and distributes these data to the missile firing batteries. In this way, each battery receives a continuous flow of fresh data on all aircraft within the defense area, and on the activities of the other batteries as well; and each battery commander is provided with all the information needed to enable him to make a proper selection of target. In addition, *Missile Master* operators observe the activities of all batteries in the system, and where necessary, are able to direct a specific fire unit to a particular target, or to prevent friendly aircraft from being fired upon. The *Missile Master* is a combination of the latest automatic electronic equipment and of human supervision imposed at the most critical points; it calls for one of the largest amount of electronic equipment ever applied to a missile system.

*

A missile is, of course, a one-shot proposition, and test pilots cannot ride rockets. Consequently, reliability in a guidance system must be 100 percent, and the key to successful design is exact knowledge of how the vehicles perform in flight. Three different methods of checking these properties have been applied in the U.S.A. The first one is a *radio telemetering system* that checks 24,000 measurements every second. Accuracy is one part in 256. When missiles are tested, additional information can be gathered by rugged portable magnetic tape recorders especially designed for acquiring engineering information during flight. This information must be compiled in a form that aeronautical engineers can use in revising their designs. Much of this data reduction can be done on giant electronic brains, such as the IBM 700 machines. However, a special-purpose computer called a data transcriber must be installed ahead of the general-purpose computer input to convert from telemetering language to computer language.

One such computer is called IDIOT. The name stands for *I*nstrument Lab *D*igital *O*nline *T*ranscriber. The machine, however, does not deserve its bad name. Far from it: IDIOT can transcribe more than three million items of information during an eight-minute test run.

A second system, which applies to subsonic missiles only, is mounted in the *nose section of a fighter aircraft,* such as Lockheed F–94. With its special nose-mounted radome, the Air Research and Development Command and its missile contractors are able to test and evaluate missile components prior to their installation in an actual test missile. The price of a missile (thousands of dollars) and countless man-hours are saved about every other day at ARDC's Air Force Missile Test Center, Florida, by using this new missile simulator test system.

A third test system—revealed only a short time ago—is the *Avco Shock Tube Speed Simulator System.* This method permits missile research with shock waves simulating flight problems at speeds exceeding 18,000 miles an hour. The high speeds, accompanied by 15,000-degree Fahrenheit temperatures are achieved in several shock tubes, one of which is a large tube believed to be the biggest hypersonic research device of its kind. The big tube is a cannon-like assembly 100 feet long. When it is fired, for the purpose of studying gases at extreme temperatures, a shock wave is created that races down the length of the tube, moving so fast that its travel time is measured in millionths of a second. The tube, a distant relative of the wind tunnel, was designed and built for Air Force missile research.

The tube can be fired either by the high compression of a combination of gases or by the explosion of a combustible mixture of oxygen and hydrogen tempered by helium and nitrogen. In either case, the thick rear section, or driver, is loaded with gas under pressure and the rest of the tube, separated internally from the driver by a strong metal diaphragm, has almost all the air withdrawn from it. Then, when the driver reaches high pressure, either through mechanical pumping of the firing of combustible gases, the diaphragm bursts and the resulting shock wave speeds down the length of the four-inch diameter tube with camera and electronic instruments "watching" it. The fact that the tubes are in operation for only millionths of a second at a time requires high speed electronic instrumentation. If they were kept in operation for very much longer, the apparatus would melt and vaporize.

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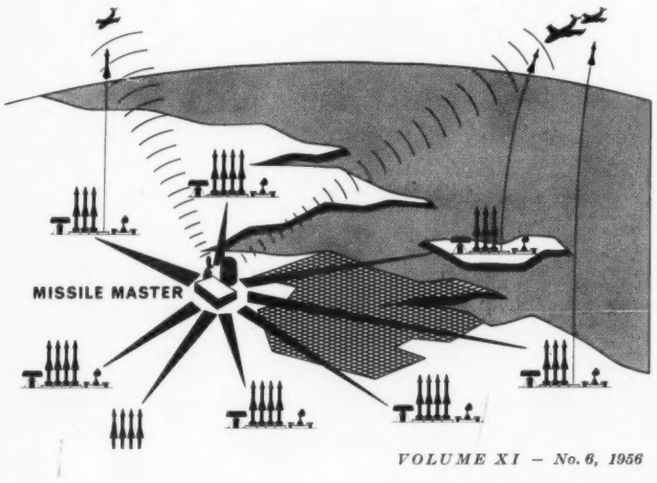
Electronic consoles, similar to these radar entry consoles in the system at Fort George G. Meade, Maryland, are the nerve centre of the *Missile Master* system.

Diagram of *Missile Master* installation controlling a ring of *Nike* missile batteries.



Testing a subsonic missile guidance system in a special cone mounted in the nose of a Lockheed F-94 fighter. Pilot can check operation of system.

It is significant that in spite of the obvious and wide advancement in electronics, radio jamming is still one of the worst headaches of the personnel at the missile test facility at Patrick AFB, Florida. Several different types of missile are launched and test flown at this sunny base every day, and numerous mishaps occur because of radio jamming. The source is usually the uncontrollable transmitting of Latin American radio amateurs! Exhaustive research is underway with the goal of developing absolutely jam-proof guidance systems.

Guided Missile Power Plants

The continued extensive research in American propellant laboratories is beginning to pay off. Remarkable improvements have been revealed in both the liquid and solid propellant fields and in ramjet development.

The U.S. Army Ordnance Corps at Redstone Arsenal, for example, has announced that one of the largest solid propellant missiles of its type, the RV-A-10, has successfully completed flight tests. The propulsion unit for this missile, jointly developed by General Electric and Thiokol Chemical Corporation as a portion of the *Hermes* program, is typical of the advancement in the science of solid propellant rocketry.

Successful performance of this rocket motor establishes the feasibility of solid propellant units for large, long-range and high-altitude missiles. Solid propellant rocket motors are, of course, relatively simple in construction compared to other propulsion systems. They also offer a decided operational advantage inasmuch as their simple and rugged construction makes handling and launching easier and safer. Among today's solid propellant rockets in production are the *Terrier, Falcon* and the *Honest John*. Based on the successful flight tests of the RV-A-10, even larger solid propellant units of this type are being developed and tested in the United States, and the U.S. Navy is particularly interested. The Navy is said to concentrate on a new type Intermediate Range Ballistic Missile, a short and stubby vehicle that poses no handling or fuelling problems.

For some time experiments with "consumable" solid propellant boosters have been conducted, and it has been suggested that such units be developed for missiles of the *Nike* type. This type of booster incorporates a plastic type propellant which permits the entire unit to burn, i. e., even the booster container or shell itself will be part of the propellant. This design concept yields a safety factor in that missile batteries might be located close to built-up areas without risking fall-out of empty booster shells on populated areas.

*

In the field of liquid propellants the most outstanding research developments during the last few months has been the announcement that industry is getting ready to manufacture a "safe" ozone. For years and years propellant laboratories have tried to develop better oxidizers, but so far only liquid oxygen and certain

mixed oxides of nitric acid, such as nitrogen tetroxide, have proved to be useful and relatively safe.

Problems of propellant selection include low price, abundance of raw materials, stability in storage, ease of handling, non-toxicity and convenient freezing and boiling points. One of the most powerful rocket propellant combinations known, liquid oxygen and liquid hydrogen, is also the most dangerous and difficult combination to handle. Although liquid oxygen is cheap to produce and can be handled safely, liquid hydrogen presents extremely difficult storage and handling problems. A rocket with liquid oxygen plus liquid hydrogen propellants would require very large and well-insulated tanks and would constitute an extremely hazardous vehicle.

The special process for the manufacture of safe, 100-percent pure ozone took three years to develop. The new-type ozone also has remarkable stability against heat, impact and vibration—all trigger mechanisms blamed for lab-shattering explosions in the past. This development is significant indeed, and it is quite likely that ozone rockets will be used in missiles on a large-scale basis within a few years. It has been said that Armour Research Foundation, developer of the new-type ozone, has submitted a proposal to the Naval Research Laboratory to use liquid ozone as an oxidizer for some of the *Vanguard* satellite main-stage rockets. In some cases the theoretical exhaust velocities obtained by use of ozone are as much as 25 percent higher than with ordinary liquid oxygen.

Guided missile rocket motor undergoing test on static test stand at Propulsion Field Laboratory of Rocketdyne Division of North American Aviation Inc., Santa Susana Mountains, California.

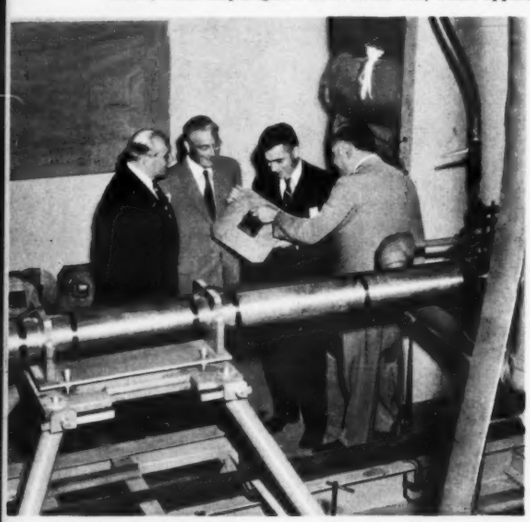
*

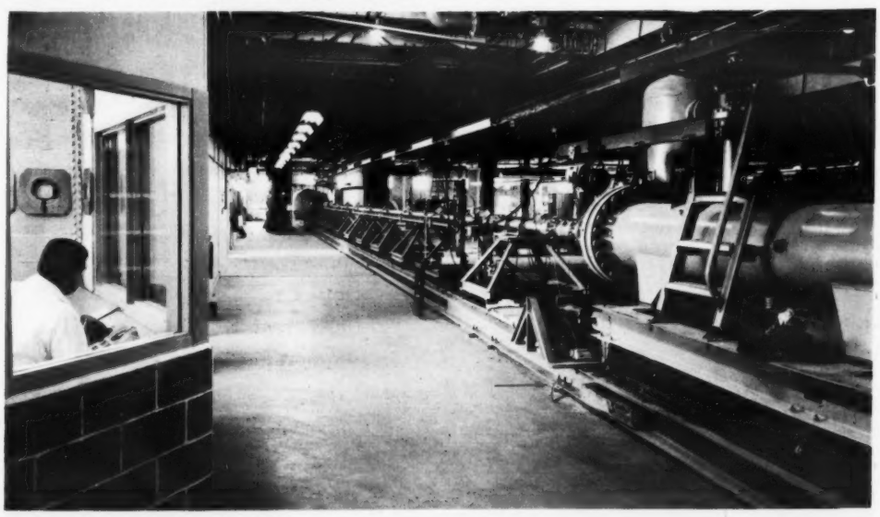
The largest U.S. liquid rocket motors demonstrated to the public (press) so far are rated at approximately 170,000 pounds thrust. This is about three times as much as the V-2 motor performance. However, it is generally admitted that rocket motors with thrust ratings above 300,000 pounds are in existence. Testing of such motors already has begun at Aerojet-General Corporation's new, giant test facility at Sacramento, Calif. Two of the great concrete test stands at the facility are capable of handling 300,000 pound loads; a third stand is designed for 1,500,000 pounds. Aerojet's test facility will ultimately be the largest in the United States. At the moment, North American Aviation's test facility in the Santa Susana Mountains, California, is still the most extensive. Motors and boosters for such missiles as *Navaho* and *Atlas* are being tested here. (North American also builds the motor for the U.S. Army *Redstone* missile. The *Redstone* booster alone yields 75,000 pounds thrust.)

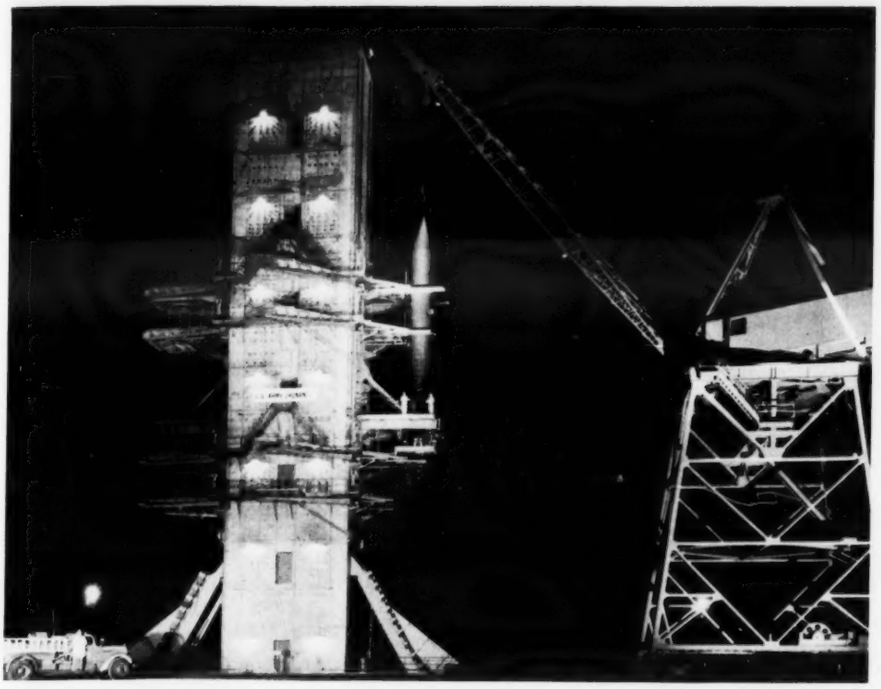
The Santa Susana facility was started in 1947, with a nucleus of five North American research engineers and a small group of Air Force propulsion experts. Today the company has several thousand persons working in the separate Rocketdyne Division, located in new headquarters at Canoga Park, ten miles from the test facility, called the Propulsion Field Laboratory. Rocketdyne's work encompasses the design and development of rocket powerplants for missiles and aircraft; small armament rockets for aircraft; and all related research and experimentation in fluid dynamics, thermodynamics, chemistry and metallurgy.

In addition to Aerojet and North American, two other companies are heavily engaged in liquid propellant rocket design and development, namely, Reaction Motors, Inc. and The General Electric Company. The latter organization is best known for its work on the different *Hermes* projects and as builder of the gasoline motor for the *Vanguard* main-stage rocket. At

Avco Shock Tube Speed Simulator at Avco's Advanced Development Division, at Everett, Mass., permits missile research at speeds exceeding 18,000 m.p.h. At *left*, Avco officials and scientists inspect pressure-burst metal diaphragm. At far left is Avco's Chairman and President, Victor Emanuel; at *right*, full view of 100-ft. shock tube. Left is control booth; when diaphragm is burst at far end, whole apparatus moves on its wheels and tracks to absorb part of force.







Static missile test stand of U.S. Army's Ballistic Missile Agency. *Redstone* missile is being lifted into place.

General Electric's propulsion laboratory in Cincinnati, chemical engineers are reported to be working on what has been termed "exotic propellants"—new high-thrust, non-hydrocarbon chemical combinations which will yield tremendous amounts of thrust when used with oxidizers such as liquid ozone. Furthermore, it is safe to say that practically every major oil and chemical company and most chemical laboratories are experimenting with and testing new propellants, and some of them are likely to be employed in production missiles shortly.

U. S. Missile Arsenal

Outstanding missile projects in the "number one" category, surface-to-surface, now include these names: Matador, Regulus, Navaho, Snark, Honest John, Little John, Corporal, Redstone, Thor, Atlas and *Titan.*

The new U.S. Air Force *Matador,* or TM-61B, takes off from a mobile launcher with a booster which puts it on its course and then a sustaining motor to carry it along very much the way an airplane would be carried on its course. However, a missile is not simply a warhead delivery wagon. *Matador* was designed as a comprehensive tactical weapons system in the rounded military sense and embraces: (1) a transonic, high performance airframe, featuring interchangeable parts; (2) means of automatic guidance; (3) alternative warheads; (4) a zero-length launcher and booster rocket; (5) a full complement of ground-handling and transporting vehicles; (6) fully equipped squadron assembly, ordnance and launch areas; (7) complete systems check-out and testing apparatus; (8) depot, housing and maintenance facilities both at the factory and in the field; (9) shipping containers for the seven major components; and (10) packaged spare parts ready for shipment and long-term storage.

The J-33-A-37 in the USAF's new *Matador* is currently being replaced by an Allison J-33 engine with higher power, a conversion of an engine originally used with a piloted aircraft. The new *Matador* missile is longer than the present USAF TM-61 *Matador,* which is the Air Force's first operational tactical missile deployed on a ready-alert status in Europe. Test firings of the TM-61B have been performed at the Air Research and Development Command's Holloman Air Force Base in New Mexico. For tactical missions, the TM-61B will be given an entirely new airborne guidance system. Production of the present line of *Matadors,* meanwhile, will continue. The U.S. Air Force has announced an additional order for a substantial quantity of TM-61 missiles.

The versatile *Regulus,* developed by Chance Vought Aircraft under the sponsorship of the U.S. Navy Bureau of Aeronautics, has increased tremendously the striking power of the Navy's surface and submarine forces. Designed for launching from submarines, surface ships and shore bases, *Regulus* is in full scale production at the company's Dallas, Texas, plant. *Regulus* can deliver a powerful warhead at transonic speeds over a range of hundreds of miles, guided along its course by a built-in electronic system. It was conceived by Chance Vought in 1947, but its existence was not disclosed publicly until March 1953. *Regulus* was designed in two versions: a recoverable test and training missile with a retractable landing gear, and a non-recoverable tactical missile.

The concept of recoverability paid off. Some *Regulus* missiles have been flown as many as 10 times and one missile has flown at least 15 times. In addition to savings in money, the recoverability concept was responsible for much of the exceptional versatility of *Regulus.* It led to new developments in certain elements of the missile system that extended the usefulness of *Regulus* far beyond its original mission. The submarine USS *Tunny* was the first underwater craft specifically modified to launch *Regulus,* but others are slated for similar con-

RV-A-10, Army Ordnance's latest, largest solid-propellant rocket, establishes feasibility of solid propellant units for long-range high-altitude rockets.

Recent Guides Missiles

Maker	Year	Type	Use	Power Plant (plus boosters)	Thrust lbs.	Length ft. in.	Weight lbs.	Range miles	Speed Mach No. or mph	Ceiling ft.	Remarks
Great Britain											
Armstrong-Whitworth	1955/56	—	Ship-ship or ship-land	—	—	—	—	Inter-mediate	—	—	Guidance system by General Electric Co. Production scheduled for 1956.
A.V. Roe (plus others)	1955/57	—	ICBM	Possibly atomic (Hawker Siddeley or Rolls-Royce)	—	—	—	Inter-continental	—	—	Still in early development phase; may have hydrogen warhead.
Bristol Aeroplane	1955/56	—	Surface-air	Ramjet	—	—	—	—	Mach 1.5+	—	For use against supersonic aircraft.
English Electric	—	—	Surface-air	Liquid rocket (?) + external launching boosters	—	—	—	—	2000+	—	Marconi guidance system; production about to begin.
Fairey	1954/55	Fireflash	air-air	Solid rocket plus boosters	—	app. 10′	—	—	Mach 1+	—	Beam guidance; proximity fuse; in production for R.A.F. To be offered for export.
de Havilland Propeller Co.	1956	—	air-air	Liquid rocket (?)	—	—	—	—	Mach 1+	—	Projected standard equipment for R.A.F. With infra-red homing head.
Royal Aircraft Establishment	1955/56	—	—	Solid propellant	—	app. 25′	—	—	—	—	First test firings at Woomera scheduled for second half of 1956.
France											
MATRA/SNCASE	app. 1952	M. 04	air-air	SEPR 251 liquid rocket	2760	15′ 1″	1010	—	1100	—	Experimental device (scale 2 : 3) for a future air-to-air rocket.
MATRA	1955/56	R. 015	air-air	Two-stage powder rocket	—	9′ 10″	350	—	—	—	Canard construction; for fighter armament.
MATRA	1955/56	AA. 20	air-air	SEPR 251 liquid rocket	2760	app. 15′	—	—	Mach 1—2	—	Production to begin in 1956; for use in *Mystère IVA and IVB*.
DEFA (Direction des Etudes et Fabrications d'Armement)	1955/56	PARCA	Surface-air	—	—	—	2200	—	Mach 1+	65,000+	Ainti-aircraft missile; launching booster; proximity fuse.
DEFA (Direction des Etudes et Fabrications d'Armement)	1955/56	ENTAC	Surface-surface	Powder rockets	—	—	—	app. 1.3	—	—	Anti-tank missile; cable guidance.
E.C.A. (Société d'Etudes et Constructions Aéronautiques)	—	ECA 20, ECA 26	Research	—	—	—	—	—	—	—	Experimental missiles for testing guidance systems.
Etablissements Jean Turck	—	—	Research	—	—	—	—	—	—	—	Development of guidance systems for guided missiles.
L.R.B.A. (Laboratoire de Recherches Balistiques et Aérodynamiques)	1950	Véronique	Research	Liquid rocket	8820	20′	2200	150	3100	213,000	Launched from firing platform; cable guidance.
SNCA du Nord/ SFECMAS	1955/56	SFECMAS 5103	Air-air	Two-stage powder rocket	—	8′ 2.5″	290	—	app. Mach 1	—	—
SNCA du Nord/ SFECMAS	about 1954	SFECMAS 5200	Surface-surface and air-surface	Powder rocket	—	—	—	—	—	—	Anti-tank rocket with cable guidance; hollow charge. Already in operation.
SNCA du Nord/ SFECMAS	—	SFECMAS 5210	Surface-surface and air-surface	Powder rocket	—	—	—	—	—	—	Derived from Type 5200; greater range.
SNCA du Nord/ SFECMAS	—	SFECMAS S.T. 450	—	Ramjet (plus launching boosters)	—	—	—	—	Mach 1+	—	—
SNCA du Sud-Est	1955/56	SE. 4200	Surface-surface	Ramjet (booster for launching)	—	—	—	app. 60	barely Mach 1	—	Fired from short launching ramp.
SNCA du Sud-Est	1955/56	SE. 4300	Surface-air	—	—	—	app. 2200	—	—	—	Performance reportedly similar to the American *Nike*.
SNECMA (?)	1955/56	MASALCA	—	—	—	—	—	—	—	—	Under development for the French Navy.
SNECMA (?)	1955/56	MARUCA	—	—	—	—	—	—	—	—	Under development for the French Navy.
Italy											
Polverifici Giovanni Stacchini	1955/56	—	Air-air, air-surface and surface-air	—	—	—	—	—	—	—	Working, with other firms, on rockets for various purposes.
Silurificio Whitehead Motofides	about 1954	Robotti A.R.4	Research etc.	Liquid rocket	—	—	—	—	—	—	—
Japan											
Shin Mitsubishi Heavy Industries	1955/56	—	Air-air	Fuji Precision rocket motors	—	—	—	—	—	—	Electronic equipment by Mitsubishi Electric Co.; production beginning.
University of Tokyo	—	Kappa	Research	—	—	—	—	—	app. 3400	app. 330,000	Three-stage research rocket.
University of Tokyo	—	Sigma	Research	—	—	—	—	—	—	—	Tests to begin later this year.
University of Tokyo	—	Baby-T	Research	—	—	42′	17.6′	—	890	app. 13,000	—
University of Tokyo	—	Baby-R	Research	—	—	46′	17.6′	—	890	app. 13,000	—
Sweden											
—	1955/56	—	Surface-air	—	—	—	—	—	Mach 2—3	—	Guided missiles of the most varied categories are under development in Sweden.

Maker	Year	Type	Use	Power Plant (plus boosters)	Thrust lbs.	Length ft. in.	Weight lbs.	Range miles	Speed Mach No. or mph	Ceiling ft.	Remarks
Switzerland											
Hispano Suiza (Swiss)	1954	8-cm shell	Air-air air-surface and surface-surface	Powder rocket	2645	3.6'	22	app. 9	1930	—	With H.E. head or hollow charge; unguided.
Oerlikon	1949	8-cm shell	Air-air and air-surface	Powder rocket	—	3.3'	22	—	1550	—	With 2.2-lbs. warhead; unguided. Also version with folding fins.
Oerlikon	about 1950	—	Surface-air	Liquid rocket	—	app. 20'	830	9—12	Mach 1.8	—	Beam guidance system; proximity fuse. Wing control, particularly after burn-out.
USA											
Aerojet-General Corp.	1947	Aerobee RTV-A-1A	Research	Aerojet liquid rocket + powder rocket	4000+	20'	app. 1320	—	Mach 4.8	370,000	Experimental device in operation.
Aerojet-General Corp.	1954/55	Aerobee-Hi AJ11	Research	Aerojet liquid rocket + powder rocket	4000+	23'	app. 1430	—	Mach 6.5	820,000+	New record altitudes are aimed at with this rocket.
Aerophysics Development	1955/56	Dart	Anti-tank	Powder rocket	—	6'	—	—	—	—	Being built for U.S. Army; cable guidance.
Bell	1953	Rascal GAM-63	Air-surface	Liquid rocket	—	20'	—	100	Mach 1.5+	app. 100,000	Federal Telecommunications Laboratory has developed a new guidance system for the *Rascal*; launched by GB-52 or GB-58.
Bell	1954/55	Shrike SAM	Surface-air	Liquid rocket	—	—	—	—	—	—	—
Bendix/McDonnell	1953	Talos SAM-N-6	Surface (ship)-air	McDonnell ramjet + booster (?)	—	—	—	—	—	—	In production; also *Talos-L* and *Talos-W*.
Bendix	1954/55	Loki	—	Powder rocket	—	—	—	—	—	—	In production.
Boeing	1952	Bomarc IM-99	Surface-air	2 Marquardt ramjets + Aerojet-General powder rocket	—	66'	8500	—	Mach 2.5	60,000+	Carries Hughes GAR-98 *Falcon*.
Chance-Vought	1951/52	Regulus SSM-N-8	Surface(ship)-surface (ship)	1 Allison J-33-A-18A jet plus two Aerojet-General powder rockets	5000+	32.8'	app. 14,300	200	600	—	In production; already in service. Command guidance. — Training version.
Chance-Vought/ Eastman Kodak	1953	Dove ASM-N-4 and -5	Air-surface (naval targets)	—	—	—	—	—	—	—	In production.
Chrysler	1953	Redstone I	Surface-surface	North American liquid rocket	65,000+	60'	—	300+	Mach 5+	—	Derived from V-2; can carry atomic warhead.
Chrysler	1955/56	Redstone II (Jupiter?)	Surface-surface (IRBM)	North American liquid rocket	—	—	—	1500+	Mach 5+	—	IRBM weapon, derived from *Redstone I*.
Convair/Bendix	1951/52	Terrier SAM-N-7	Surface (ship)-air	Aerojet liquid rocket + powder rocket	—	14.8'	3350	15	Mach 2.0	app. 50,000	Beam guidance; in service. Also *Terrier* 1 and *Terrier* 2.
Convair	1955/56	Tartar	Surface (ship)-air	—	—	—	—	—	—	—	In production. Smaller than *Terrier*, with same destructive effect.
Convair	1955/56	Atlas SM-65	Surface-surface (ICBM)	North American liquid rocket	app. 120,000	app. 100'	225,000 to 500,000	5000+	Mach 15	app. 800 miles	ICBM with hydrogen warhead
Cook Research & Laboratories	1956	Cherokee, Skokie I, Skokie II	—	—	—	—	—	—	—	—	For U.S.A.F.; supersonic speeds.
Douglas	1956	Ding-Dong	Air-air	North American liquid rocket	—	—	—	—	—	—	Under development for U.S.A.F.; Hughes guidance system; with atomic warhead.
Douglas	1956	Bird Dog	—	—	—	—	—	—	—	—	Under development.
Douglas/Western Electric	1950/51	Nike SAM-N-7	Surface-air	Aerojet liquid rocket + powder rocket booster	—	app. 20'	1000	app. 20	Mach 2.0	65,000+	In service, also overseas; *Nike B* is a slightly larger, more effective version.
Douglas/Emerson	1953	Honest John	Surface-surface	Hercules powder rocket	—	27'	5950	app. 20	Mach 1.5	—	In service; unguided artillery rocket.
Douglas/Emerson	1956	Little John	Surface-surface	Hercules powder rocket	—	—	—	—	—	—	Derived from *Honest John*; smaller range.
Douglas/Sperry/ Raytheon	1951/52	Sparrow AAM-N-2	Air-air	Aerojet powder rocket	—	8' 3"	280	app. 6	Mach 3.0	—	In production and in service; also AAM-N-3 and N-4.
Douglas	1955/56	Thor	Surface-surface (IRBM)	—	—	—	—	app. 1500	—	—	Under development.
Fairchild	1954	Petrel AUM-N-2	Surface-underwater	Fairchild J-44 jet	1000	—	1500	—	Mach 0.7	—	Anti-submarine missile; can also be launched from helicopters.
Fairchild	1955/56	Goose AUM-N	Surface-underwater	Fairchild J-83 or GE J-85 jet	2000	—	—	—	—	—	For long-range operations; under development.
Firestone	1952/53	Corporal E SSM-A-17	Surface-surface	Liquid rocket (Jet Propulsion Laboratory)	app. 20,000	40'	app. 12,000	app. 125	Mach 3.0	—	Gilfillan beam guidance; also Corporal F; in production and in service.
Hughes/Philco	1950	Falcon GAR-98	Air-air	Thiokol powder rocket	app. 200	6'	112	up to 6	Mach 3.0	—	Fighter armament; in production. Also *Falcon* 2 and *Falcon* 3.
Martin	1949	Matador TM-61 A	Surface-surface	Allison J-33-A-17 + powder boosters (later versions to have more powerful J-33)	4600+	39' 5"	12,000	up to 620	Mach 0.9	45,000	Guided bomber; also TM-61B (longer), TM-61C and TM-61D. In service.
Martin	1955/56	Titan WS-107	Surface-surface (ICBM)	Liquid rocket (North American?)	—	—	—	app. 5000	—	—	Under development.
Martin	1954/56	Bullpup ASM-N-7	Air-surface	Aerojet-General powder rocket	—	11'	—	—	—	—	Under development.
North American	1954/56	Navaho SM-64	Surface-surface	2 Wright ramjets + North American liquid rocket as booster	—	—	—	app. 5000	Mach 3.0+	—	Under development in several versions.
Northrop	1955/56	Snark SM-62	Surface-surface	Allison J-71 jet + 2 boosters of 33,000 lbs. each	app. 10,000	74'	app. 35,000	2000+	Mach 0.9	—	In production.
Philco/Martin	1954/56	Sidewinder AAM-N-7	Air-air	—	—	—	—	—	—	—	In production; infra-red homing head.
Raytheon	1954/55	Hawk SAM	Surface-air	Liquid rocket	—	—	—	—	—	—	Production begun.

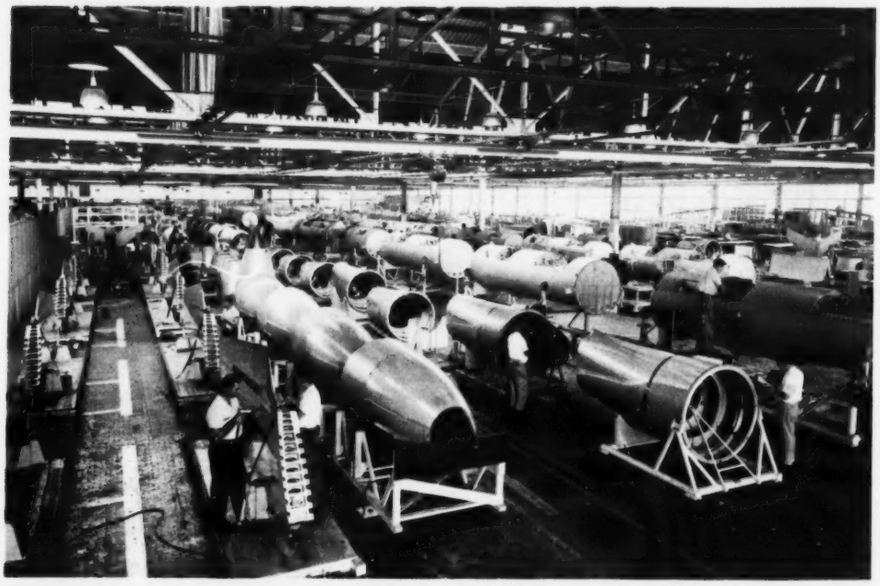
version. Each carries a special tank for storing *Regulus* and a launching ramp. Navy crews have successfully launched *Regulus* also from cruisers, aircraft carriers, small surface ships and portable launchers ashore.

*

Supplementing the line of manned bombers, there are two categories of strategic surface-to-surface long-range missile, the ballistic or rocket-like missiles (ICBM), such as the Convair SM-65 *Atlas* and Martin *Titan*, and the air-breathing types (Northrop SM-62 *Snark* and North American SM-64 *Navaho*). The latter will have range, accuracy and load carrying capabilities at least as good as the ballistic missile, but will be easier to intercept. In addition, a possible Russian threat is to be met with an intermediate range missile (IRBM).

New version of Martin *Matador* tactical missile, designated TM-61B.

Martin TM-61 *Matador* missiles in production. *Matador* is made in seven major parts: wing, nose, aft-tail, centre section, fin section, stabilizer section and instrumentation.



Earlier TM-61 *Matador* remains in production. This one is "somewhere in Europe."

United States Defense Secretary Charles E. Wilson has appointed Eger V. Murphree, President of Esso Research and Engineering Company, as missile "czar" to coordinate all activities in the complex race for the ballistic missile (ICBM and IRBM). He will work with an estimated $2,000,000,000 annual appropriation.

The first project in the ICBM field—the *Atlas*—has been under development for a number of years. The overall contract for this tremendous missile has been awarded to the Ramo-Wooldridge Corporation of Los Angeles, the Rocketdyne Division of North American Aviation and Aerojet-General Corporation. The Convair Division of General Dynamics Corporation is building the hull and tanks, and General Electric is responsible for the electronic components.

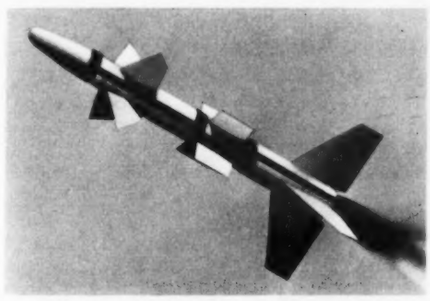
A second ICBM, the *Titan*, is being developed by the Denver Division of The Glenn L. Martin Company of Baltimore, Maryland. *Titan* will use many of the components—such as the motors—being developed for *Atlas*. This plan enables the U.S. Air Force to conduct simultaneous development of two operational missiles, representing different technical approaches, at little extra cost.

Some experts say that each individual ICBM will cost between $4,000,000 and $5,000,000. The optimism of Air Force officials about the future of their guided missile program has been indicated in testimony that 20 per cent of the money earmarked for aircraft and major procurement in the fiscal year starting July 1st would go into guided missiles. In the current year it is only 12 per cent. By 1958 more than 33 per cent will be allocated for missiles. By order of the Joint Chiefs of Staff, the ICBM now has priority over practically every other research and development project in the United States. The basic research of the ICBM weapons is being done in three ultra-secret NACA laboratories: at Wallops Island, Va.; in Cleveland; and at Moffett Field, Calif. Here, brand-new metallic materials are being evolved, engines that employ hitherto unheard-of-principles of propulsion tried out, and missiles with fantastic, futuristic shapes tested.

At a rough estimate, each of these ICBMs will be a three-stage rocket about 85 feet long and 10 feet in diameter. The wingless final stage

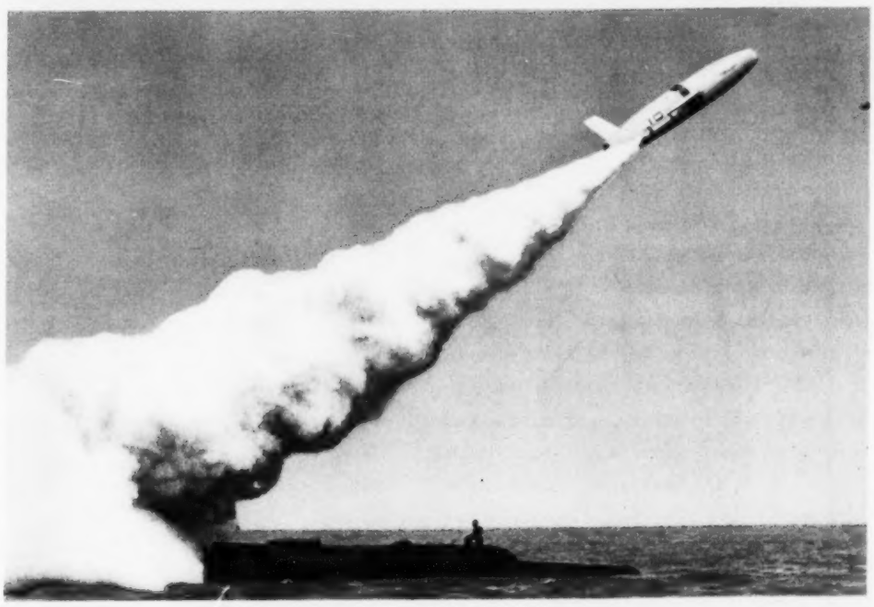
will be about 30 feet long and 4 feet in diameter. Launching weight is estimated at more than 100 tons, total thrust at 150 tons, and burn-out velocity at 10,000 m.p.h. On a 5,000-mile trip the missile will travel at altitudes well outside the earth's atmosphere and reach its destination in about 30 minutes. Field Marshal Viscount Montgomery recently hinted that the Western world might have operational ICBMs by 1961.

As in the case of the ICBM program, alternate lines are being followed also in the *intermediate range or IRBM missile development*. In the IRBM case, however, the U.S. Army and Navy jointly are pursuing one line, the Air Force the other. Again in the IRBM field some of the ICBM components are applicable and are being made available to the IRBM contractors.



Bendix *Talos*, developed for Navy, will be issued to U.S. Continental Air Defense Command.

In addition to the older rocket-type missiles *Corporal* and *Honest John*, the U.S. Army has put much effort into the powerful *Redstone* missile. Under supervision of Dr. Wernher von Braun, *Redstone* was developed as a 300 mile range weapon. However, development of a new type of intermediate range (IRBM) is now underway. An entirely new missile design-wise, the new-type *Redstone* will be built for a 1500-mile range. The Defense Department has given Chrysler Corporation a major responsibility as prime contractor for the development and production of the *Redstone* surface-to-surface ballistic missile system. For more than three years, Chrysler



Navy's versatile Chance Vought *Regulus* is now launched on cart by catapult. Cart is jettisoned after launch *(top)*.

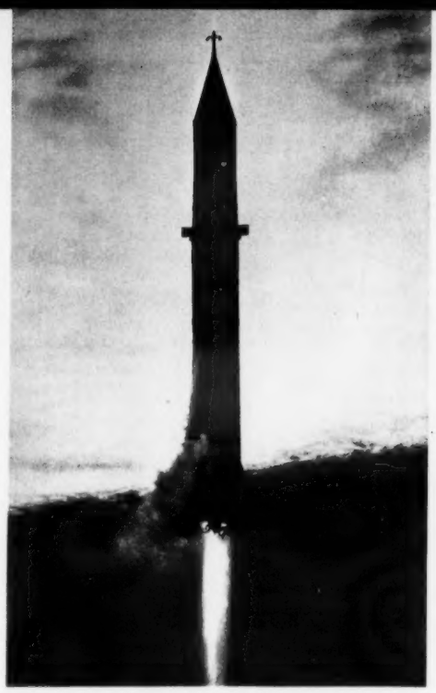
Regulus is fired from submarine USS *Tunny* with the aid of JATO boosters *(center)*.

Convair *Terrier* is U.S. Navy's first operational anti-aircraft missile *(bottom)*.

Corporation has been the prime contractor on the old *Redstone* missile.

Little John is a "free" (unguided) rocket descended from the crude but operational *Honest John*. It is small enough to be transported in ordinary trucks, and will do the duty of divisional artillery. *Little John* can carry an atomic charge, and many can be fired at the same time, so the effect behind enemy lines should be considerable.

For the Air Force IRBM or Thor program, the Douglas Aircraft Company of Santa Monica, California, has been assigned a development responsibility similar to that of Convair and Martin in the ICBM program. The Air Force ballistic missile program, including *Atlas, Titan* and *Thor*, is managed by the Air Research and Development Command, headed by Lieutenant General Thomas S. Power. Immediate control and supervision over this program are exercised by Major General B. A. Schriever, Commander of the Western Development Division of ARDC, with headquarters in Los Angeles, California. Backed by the vast resources of ARDC and its ten research, development, and test centers, WDD currently supervises the activities of the thousands of military and industrial specialists who are already actively engaged in these three ballistic missile projects. Within the Western Development Division, three organizational elements guide the operations—the staff of the Western Development Division, the Special Aircraft Project Office of the Air Material Command which provides expedited procurement and similar material functions, and the



Redstone ballistic missile has 300-mile range. New 1500-mile range version is under development.

Ramo-Wooldridge Corporation of Los Angeles which, under contract, provides WDD with a closely integrated technical staff, with specific responsibility to furnish systems engineering and technical direction to more than a dozen major contractors. In addition, a group of the nation's outstanding scientists, under the chairmanship of Dr. John Von Neumann, contributes to this vital program as advisers.

Navaho still has high priority. A long-range missile, it has wings, flies in the atmosphere much more slowly than a ballistic missile in dragless space and is therefore more vulnerable to enemy attack. But it has advantages. Carrying a thermonuclear warhead, it steers by celestial navigation. Unlike the ICBM, *Navaho* can be instructed to zigzag and feint. When *Navaho* nears its target, it can feel for the warmth of a darkened city (passive homing).

*

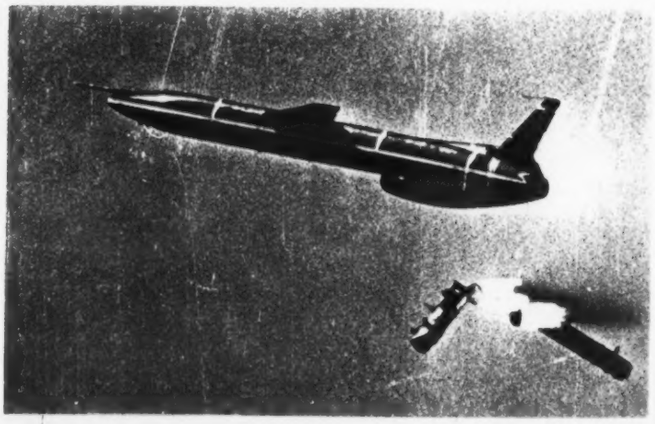
In the surface-to-air category the current production missiles include Nike 1 and Nike B, Terrier, Bomarc and Talos. Under development is Tartar, derived from Talos.

The U. S. Department of Defense actually has announced plans to use the Navy *Talos* in the air defense of the United States. *Talos* will be employed by the Continental Air Defense Command, at land installations and aboard ship. Developed by the U. S. Navy and built for them by Bendix Aviation Corporation, *Talos* is a rocket-ramjet missile. Detailed capabilities are secret. In the near future U. S. Air Force survey teams will make a study of prospective sites for *Talos* in the continental United States. The first of these will be at Lockbourne AFB, Ohio; Bunker Hill AFB, Indiana; and near Peoria, Illinois; and Kirksville, Missouri. Funds have been authorized for conversion of a light cruiser to a guided missile ship which will be equipped to utilize *Talos* within its armament. The Navy has also requested further funds for additional light cruisers to carry *Talos*.

The Boeing *Bomarc* is a supersonic, long-range anti-aircraft missile launched from the ground. Boosted into the air by an Aerojet rocket motor, it flies during most of its course on two ram-jets. It carries a warhead whose fireball is stated to be capable of knocking out more than one bomber of an invading forma-

Artist's conception of a Northrop *Snark* battery. Hydraulic jacks place the missile in position. Last-minute checks are being made from mobile platforms, while electronic computers calculate firing data *(left)*.

Northrop *Snark's* rocket boosters fall away after missile reaches flying speed on its gas turbine engine. Range is about 2,000 miles *(below)*.



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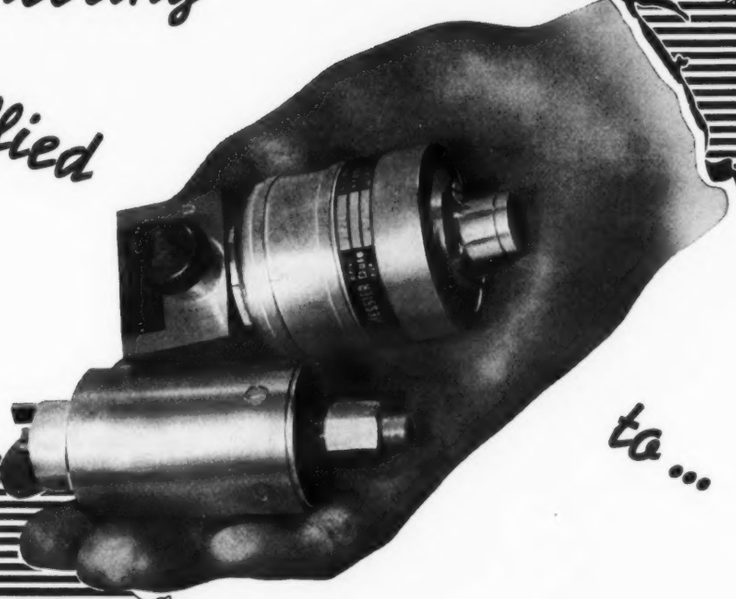

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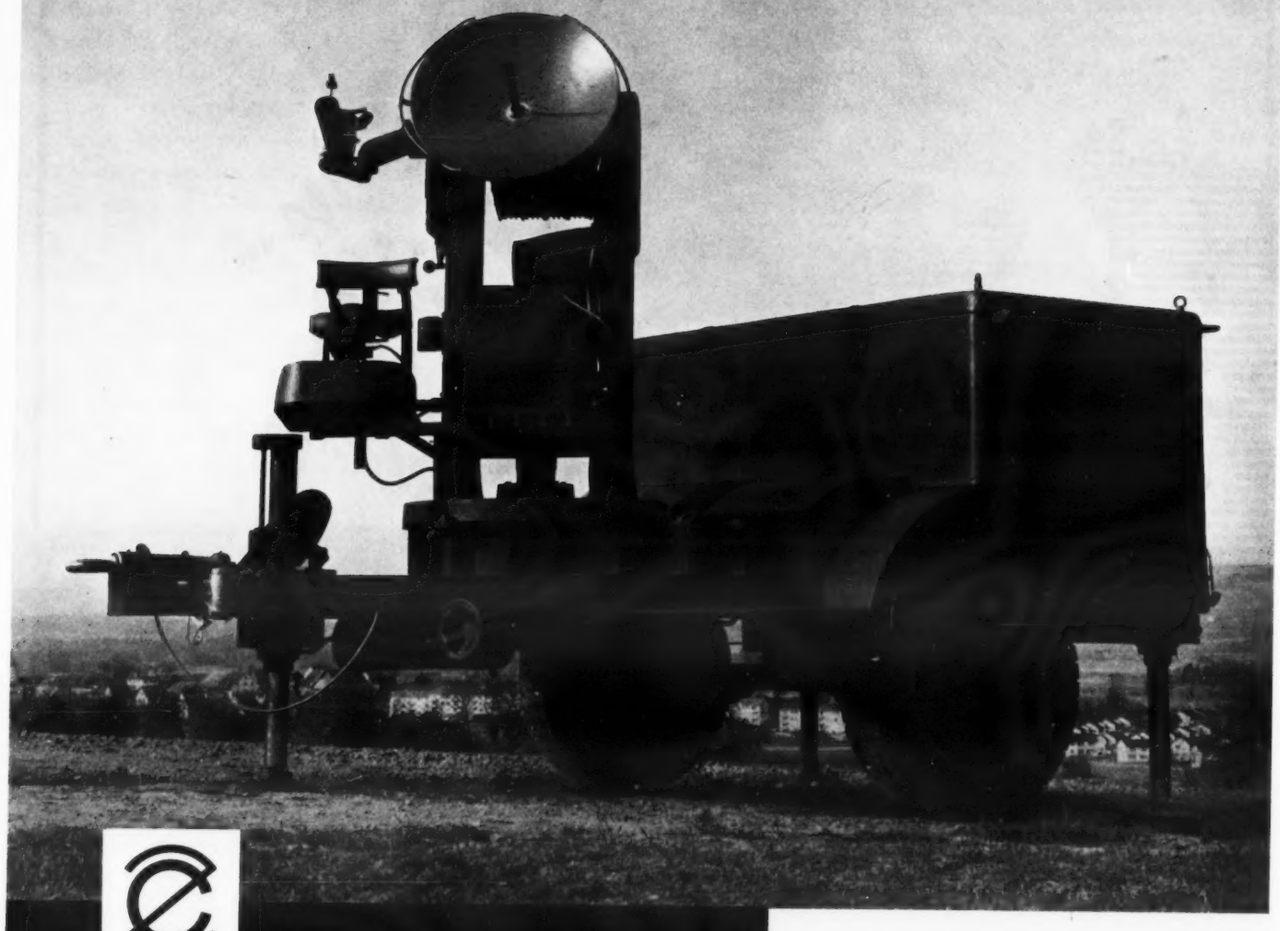

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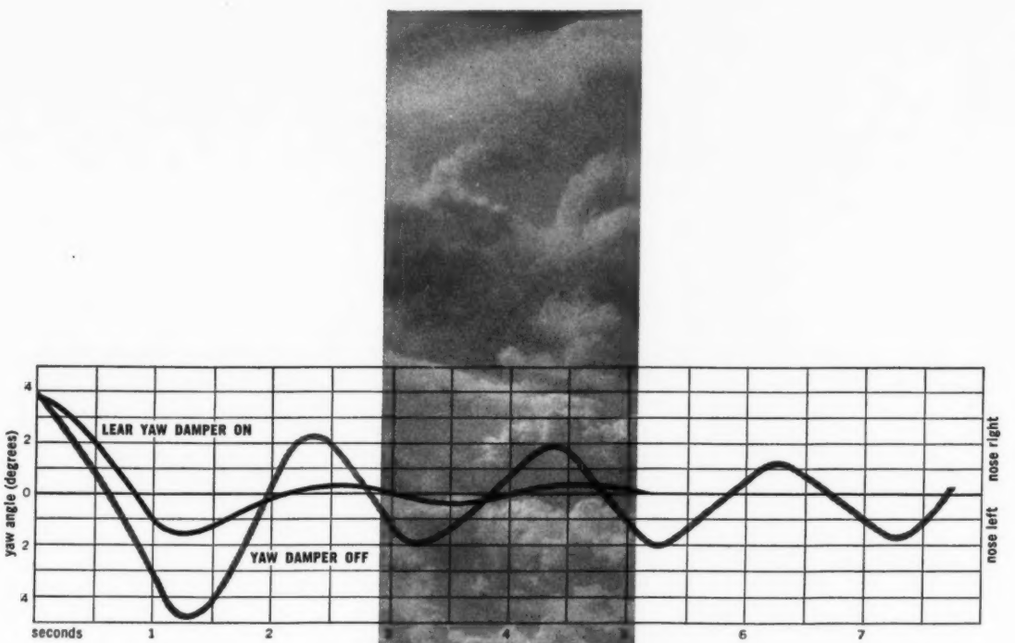
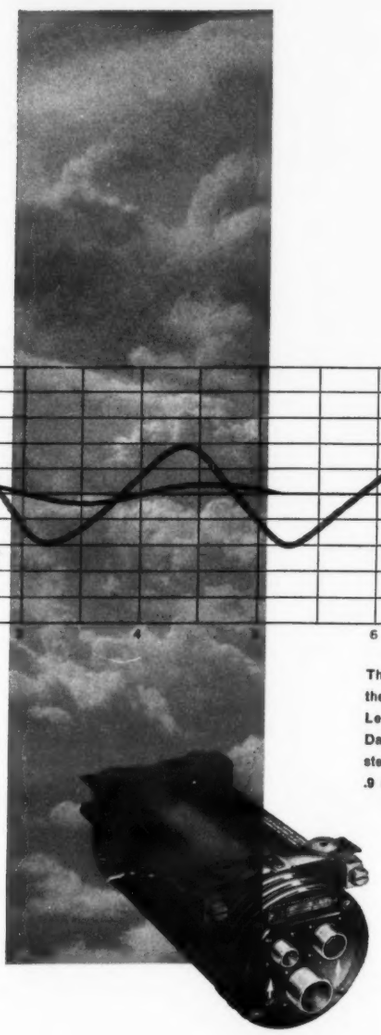


The NAA data presented here show the difference in damping time between Lear Yaw Damper "off" and Yaw Damper "on" operation, starting from steady side slips with full rudder, at .9 Mach number, altitude 40,000 feet.



to increase "hit" probability

Weapon system design combines many arts for the purpose of annihilating the enemy. The spectacular stabilizing effect of the Lear Yaw Damper on the flight path of the F-86D Sabre is shown in the above curves prepared by North American Aviation, Inc., for the enlightenment of fighter pilots. "From these data," says NAA, "it is clearly seen why the yaw damper is an essential device to make your airplane a more effective and efficient rocket firing platform."

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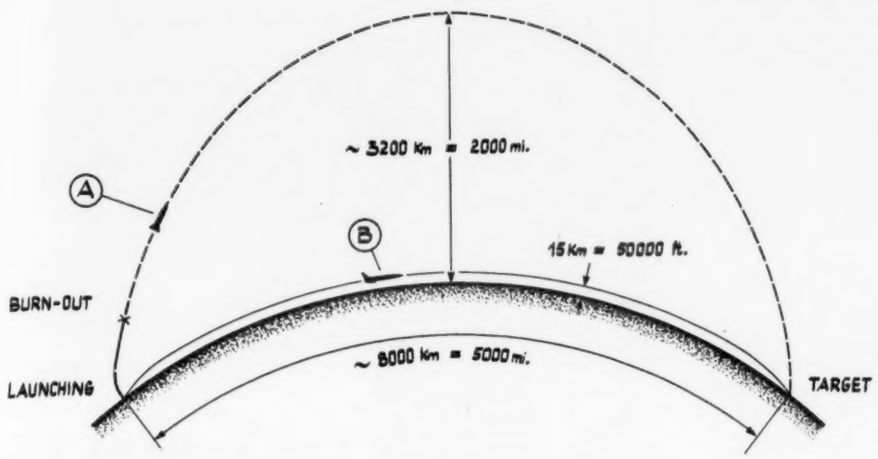
IP-8

LEAR PITCH, ROLL, AND YAW DAMPERS ARE AVAILABLE IN ELECTRONIC, MAGNETIC, AND TRANSISTORIZED VERSIONS, ENGINEERED TO THE PERFORMANCE OF THE CENTURY SERIES FIGHTERS



Difference between ballistic and non-ballistic (air-breathing) intercontinental missiles. The ballistic missile (A) is fired vertically and after burn-out flies free along elliptical path, rising to an altitude of up to 2,000 miles for a range of 5,000 miles. The non-ballistic air-breathing missile (B), e.g., the *Snark*, stays within the atmosphere at an altitude of about 50,000 feet and is guided along the entire flight path.

tion. When in operaton, *Bomarc* will be stationed in sheds on likely tracks of enemy bombers.

The *Nike* systems, referred to previously in connection with the newly developed *Missile Master* systems, continue to make up the basic anti-aircraft defense of continental United States. Admittedly the *Nike* missile is not up-to-date. Unless the U. S. Department of Defense intends to replace the current *Nike 1* and *Nike B* with *Talos*, it is rather likely that a still more advanced type *Nike* will be ordered.

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In the air-to-surface category the U. S. Air Force has numerous types of unguided solid attack rockets. Actual missiles with electronic guidance systems in this group are Dove, Rascal, Bullpup and *Petrel.*

The most significant of these is *Petrel,* possibly one of the most deadly weapons devised. This missile is produced by the Guided Missile Division of the Fairchild Engine and Airplane Corporation. It performs with "a degree of reliability considered exceptionally high for such a sophisticated weapon". A number of patrol aircraft already are equipped with *Petrel,* designed primarily for use against enemy ships at sea. Launched by patrol aircraft well outside the range of the target's air defense, the new missile thus will save the pilot from the anti-aircraft hazards which attack pilots met in World War II when they closed in on the target. Although it has not been confirmed officially, *Petrel* is a torpedo type missile capable of seeking out and hitting a submerged submarine. The same principle applies to the *Bullpup*, built by Martin, Baltimore. Bell Aircraft's *Rascal* and the Chance Vought/Eastman Kodak *Dove* are also on the classified list.

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In the air-to-air category two missiles are in full production, the Hughes Falcon and the Sperry Sparrow.

The accuracy of the *Sparrow 1* system has been demonstrated by hundreds of launchings against drone targets. Successful attacks have been completed against high-speed jet aircraft and against other missiles. This defensive weapon is considered a powerful deterrent against attack by high-speed jet bombers and fighters, and operational squadrons have now been assigned to carriers. Additional carriers of both Atlantic and Pacific fleets, including the super-carrier *Forrestal,* will be equipped with squadrons of Chance Vought F7U-3M *Cutlas* jet fighters armed with the *Sparrow I* missiles as the ships are deployed overseas. The Sperry Gyroscope Company has current contracts of "more than $50 million" for the missile guidance radar and test equipment and for production of *Sparrow I* missiles; they are manufactured at the Sperry Farragut plant in Bristol, Tennessee. *Sparrow I* is propelled by a solid rocket motor to a velocity in excess of "1,500 miles per hour within seconds" after launching. Launching of missiles may be singly or in rapid succession. Missile wings deflect in response to guidance signals to direct the *Sparrow I* to intercept the target, even under evasive action.

The U.S. Air Force announced actual production in 1955 of the Hughes *Falcon* air-to-air guided missile. *Falcon* is small and light enough to be carried in quantity by a small interceptor and can be fired in salvos. The U.S. Air Force has said that this missile, launched at a range of miles, not yards, gives interceptor pilots better odds in combat than they have ever had before. First, *Falcon* can be launched from well beyond the reach of an enemy bomber's defense. Second, it can be launched on a climbing course from an interceptor that is far below the enemy bomber. Third, *Falcon* has an extremely high probability of kill, even against maneuvering targets.

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Highly secret developments have been undertaken in the more unconventional missile categories, namely, underwater-to-air, underwater-to-surface and *underwater-to-underwater.*

Initiated by the German submarine commander H. Steinhoff late in 1944, a small group at Peenemünde headed by Wernher von Braun, went to work on underwater-to-surface rockets. A launching rack holding 6 solid *Borsig* missiles was mounted on the deck of a submarine. The rockets were fired one by one from depths up to 300 feet. The angle of the launcher was approximately 45 degrees, and the Germans discovered that the efficiency of the system was rather remarkable. Due to

Army's Douglas *Honest John* artillery rocket in Japan.

Sperry *Sparrow I* air-to-air missile is now operational with U.S. Navy squadrons, particularly Chance Vought F7U-3M *Cutlass* jet fighter, which carries four.

U.S. Navy's Sperry *Sparrow I* air-to-air missile mounted to a Chance Vought F7U-3M *Cutlass* naval jet fighter.

water back pressure the rockets hardly burned any propellant until they reached the surface; the missiles then zoomed aloft and were capable of covering almost the same distance as they normally traveled when launched from a surface installation. Due to a controversy between the German admiralty and the Peenemünde establishment the underwater rockets were not developed further by the time the war ended, but the Soviets took over the equipment and are said to have developed the system to the extent that they can fire solid propellant rockets from 300 foot depths and reach surface targets 150 miles away. In the United States Aerojet-General Corporation has conducted extensive experiments at Key West, Florida, with underwater rockets, and industry sources n the United States predict that some details about American underwater missiles will be revealed in the not too distant future.

The U.S. Navy is of course rather concerned about all the "foolproof" anti-submarine devices and weapons developed since the last war. As a counter-measure much time and effort are devoted to study and development of missiles that can be launched from submerged submarines against attacking aircraft. Furthermore, the "best trick of all" in the Navy's future will be to launch large ballistic missiles from submerged positions. If the submarine is nuclear powered, with an almost unlimited cruising period, it can be stationed for months off an enemy coast. Built with a watertight chamber to hold a large missile, the submarine will poke to the surface an electronic scanner for accurate positioning. At its leisure —in darkness and silence— far below wave motion, it will open its missile chamber and send aloft its destructive ballistic-type rocket which will rise from the surface in an inferno of flame and a cloud of steam.

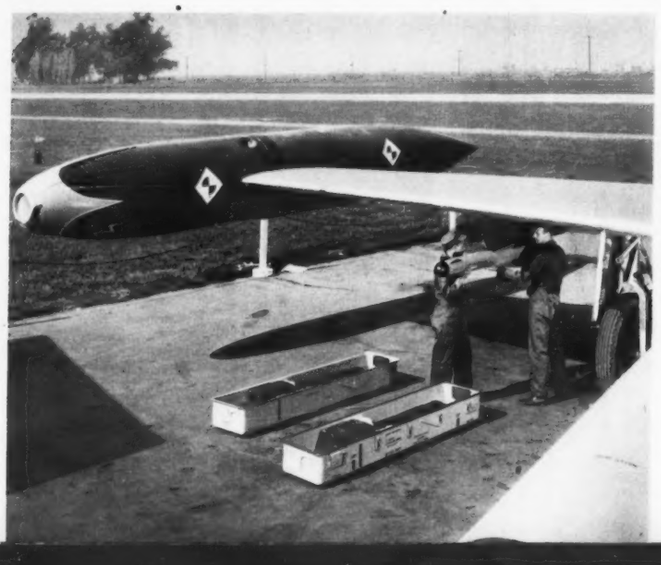
In addition to these types of submarine missiles, the U.S. Navy supposedly has developed entirely different and revolutionary underwater-to-underwater missiles, a sort of super torpedo that can be used from one submarine against another.

Rounding off American guided missile science is the significant fact that study contracts have been awarded for possible development of *anti-missile missiles*. Four different projects are said to be underway, two by Bell Telephone and Cornell Aeronautical Laboratories for the U.S. Army Ordnance and two by Convair and North American Aviation for the U.S. Air Force. The anti-missile missiles will be designed to combat high-flying intercontinental missiles.

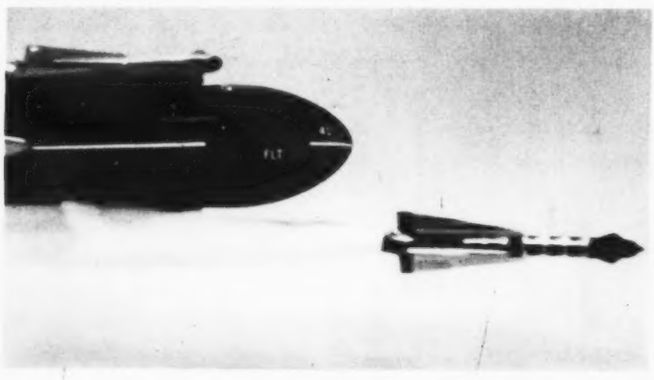
Soviet Missile Progress

Because of extensive experimentation with German V-2 type missiles, the Soviet might well possess a more substantial experience than the U.S.A. in actual operation of ballistic type missiles. But it is presumably safe to say that the United States is still ahead of the Soviet as

Mounting a *Falcon* to an underwing pylon of an F-89H. Other *Falcons* are carried in wing tip pod.



A Hughes *Falcon* air-to-air missile an instant after launching from the wing tip pod of a Northrop F-89H *Scorpion* long-range fighter. Another *Falcon* is ready for firing outside the pod.



far as missile technology, production and electronics are concerned.

Work on Soviet ICBMs has been revealed by the top Soviet leaders themselves. According to a *United Press* dispatch from Moscow of December 30th, 1955, during the days when President Eisenhower and the Soviet leaders were exchanging rather sharp notes of criticism, Premier Nikolai Bulganin hinted that the Soviet has an intercontinental or "trans-oceanic" rocket. Soviet Communist Party Leader Nikita Khrushchev said in London on April 23rd that Soviet Russia expects to have an ICBM with a hydrogen warhead in the near future.

While this does not mean that the Soviet already has a stock pile of ICBMs, it should be remembered that Soviet rocket interest goes back many years. In 1903, Professor K. E. Ziolkowsky described a liquid propellant rocket motor and in 1914 he presented a mathematical theory of rocket flight. When the Soviet took over Russia, the country continued to follow rocket developments with great interest. Putting security clamps on their programs, they began military rocket development in the mid-thirties. The first products resulted in a wide variety of artillery rockets for the army.

As early as 1946, Marshal Konstantin Vershinin (then Commander-in-Chief of the Soviet Air Force) reportedly asked Stalin to establish an independent rocket force. But—or so the reports go—he was not able to prevail over the conservative attitude of the Army and Air Force and so was replaced by General Pavel F. Zhigarijev. However, mass production of tactical rocket missiles, most patterned after the V-2, has been under way for years at a dozen different plants.

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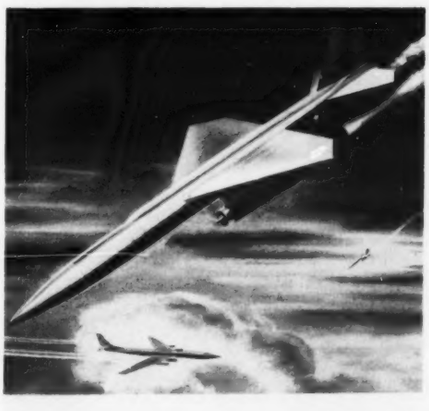
Although not yet very efficient, Russian anti-aircraft rockets have existed for a long time, according to American sources. The weapons factory at Sestrovetsk, 21 miles northwest of Leningrad, makes them. This factory employs approximately 10,000 men, although some of them are constructing anti-aircraft guns. Another factory in Tomsk is worth mentioning. It is believed to be developing weapons similar to the German Rheinmetall-Borsig R-1 and R-3 *Rheintochter* rockets. Other V-2-like missiles are manufactured in various plants in Kiev and at Irkutsk, on Lake Baikal. At Badakshan, in the Province of Turkestan, the southernmost territory of the Soviet Union, are several plants that produce missiles. In summary, Soviet's missile arsenal is as substantial as that of the U.S.A.

Fairchild *Petrel* is "sophisticated" air-to-surface or air-to-underwater missile. Lockheed *Neptune* carries two under wings.

As in the United States, the starting point of large Soviet missile hardware was the German V-2. In addition to obtaining parts and intact missiles, the Soviet actually resumed production. As many as 2000 V-2s are said to have been produced and used for high altitude research programs, production experience and for training personnel in testing and field operations. Two logical expansions of this program were the immediate development of the improved model T-1 and the T-4 winged counterpart. Further extensions of these are the T-2 long range missile, the T-3 intercontinental ballistic missile and the T-4A supersonic glide missile. These developments probably form the nucleus of Soviet tactical and strategic long range weapons. Other long range weapons were offshoots of the German V-1 and are similar to the *Matador* and *Regulus*. For army field use, a variety of artillery and nuclear armed rockets are available in operational numbers.

Boeing *Bomarc* is supersonic long-range anti-aircraft missile launched from ground or mother aircraft. It is powered by ramjets.



The Soviet's mastery of high thrust rocket engines has made possible the production of large rockets. Fairly standard oxidant systems (liquid oxygen, nitric acid and hydrogen peroxide) are being used. It appears that peroxide is being used more widely in Soviet Russia. The Soviet trend is to use simpler and cheaper and easily produced high performance composite propellants. Here again, the Soviets have made some rather large solid propellant motors. The T-7A, for example, may be looked on as an artillery rocket that can be armed with nuclear warheads and that has the simplicity of the American *Honest John* and the range of the *Corporal*. Newer composite propellants with reduced temperature sensitivities are finding useful applications in ballistic and guided aircraft rockets that can operate in the rigors of the Soviet northland.

Several East German plants produce parts, especially radar tubes and measuring and control instruments for Soviet missiles. These include the Radio-Werke Nr. 1 plant in Erfurt and the RFT-Werke and plants in Leipzig and Zwickau. Furthermore, an institute for research in aerodynamics has been established on the island of Rügen, which is a rocket base.

Guided missiles

Not Quite so Secret

BY INTERAVIA'S LONDON EDITOR

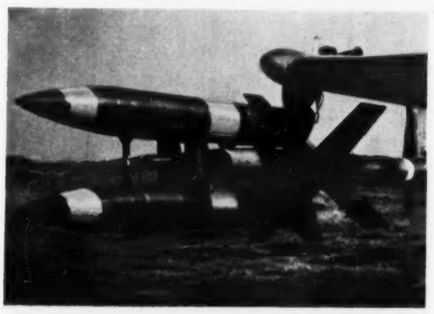
An English Electric test vehicle has just left the ramp.

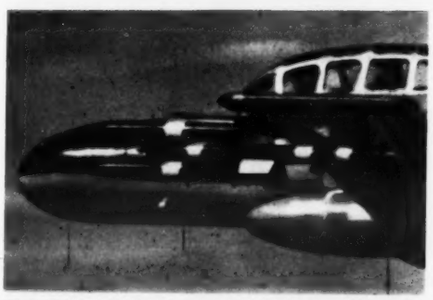
Twelve months ago we summed up the British guided weapons effort in four words, "Hush, it's Top Secret." Now the iron curtain of security has clanked laboriously a little to one side to reveal the bare outlines of the general programme, a few of the units involved, and the extent of the research effort behind them. At this point the curtain's actuating mechanism appears to have become stuck, although the journalist must be thankful for small mercies.

Basically, Britain has embarked upon a very long-term weapons programme with the twin ultimate aims of providing an automatic "push button" defence system and a hydrogen warhead intercontinental ballistic missile. As an intermediate stage, advanced air-to-air weapons for the next generation of fighters are being pressed forward with increasing energy.

That "push button" defence is still a long way off—even for an island the size of the United Kingdom—is emphasized by the fact that almost unlimited general duties commissions continue to be offered for suitable pilot entries to R.A.F. Fighter Command, together with higher rates of pay and better pensions. It is hardly likely that a Government in the throes of a budget squeeze would accept such a financial liability if it felt that the perfected ground-to-air weapon were just around the corner.

It is clear that during the past year or two there has been a lot of rethinking on missiles in the U.K., following the assembly of basic research data from the fact-finding programme initiated in 1950. Some weapons have fallen by the wayside because their performance would not give them superiority over the next generation of supersonic aircraft, or because their guidance systems were found to be too easy to jam. A smaller number of weapons are now being proceeded with, and the guidance systems problem, while far from solved, does at least seem to have been sorted out.





First British air-to-air missile is the Fairey *Fireflash*, which is composed of the missile proper and two overlap booster rockets *(top)*.

A *Fireflash* in place at the wing tip of a *Meteor* N.F.11 night fighter *(centre)*.

Fireflash destroys a *Firefly* propeller-driven target drone (about two years ago). Actually this is a near-miss and the missile was detonated by its proximity fuse. The target was knocked down *(below)*.

In defence, the air-to-air weapon will be supreme for some years. As the ground-to-air missiles are perfected they will be sited round the islands and interlinked with the long-range early warning radar network which is already in existence.

For a long time, after the introduction of ground-to-air weapons, they will be used in parallel with fighters, both systems working off the same radar network. Later the long-range radar will feed tactical radar which will assess the strength and direction of the enemy and in its turn will be monitored by computers serving the missile sites. There the target information will be fed to the local command-guidance or beam-rider sets, whichever is appropriate.

To achieve this will require not only tremendous efforts by the missile firms themselves, but also a site construction programme of unprecedented size and complexity. Also, once in being, the whole system must be kept going night and day without a break all the year round, which will pose great maintenance problems.

Whereas previously the various Ministry establishments worked hand-to-mouth with the sparse information available, the experience gained in six years and new computer test techniques evolved have enabled them to think in terms of five-year steps ahead. This is beginning to apply to industry.

With guided weapons the Government is also thinking of future production by the aircraft industry and exports abroad. The geographical conditions in the United Kingdom, with closely linked cities, small overall area, and complex transport systems, bear much more resemblance to Europe generally than do

those of the U.S.A., and weapons for U.K. defence might be more suitable for N.A.T.O. countries than those intended for continental coverage.

The official missiles set-up in the U.K. has recently been revealed as follows: (1) the Controller of Electronics and Guided Weapons at the Ministry of Supply, in conjunction with the Director General of Atomic Weapons; (2) the Royal Aircraft Establishment at Farnborough which co-ordinates the various programmes, and below this other specialized establishments, namely: (3) the Radar Research Establishment at Malvern (electronics); (4) the National Gas Turbine Establishment at Pystock (engines, particularly ramjets); (5) the Rocket Research Establishment at Westcott (development and sometimes production of rocket motors and fuels); (6) the Explosives Research and Development Establishment at Waltham Abbey (warheads, fuses etc.); and (7) the Admiralty Signals and Research Establishment at Portsdown (naval weapons' electronics etc.).

Test firing is carried out at a large range at Aberporth, Cardigan Bay, Wales, and to a small extent at Larkhill on Salisbury Plain. Another comprehensive missile range is being built in the outer Hebrides and rockets will be tested at a new site at Spade Adam waste in Cumberland. This activity only covers the United Kingdom, and there is of course the vast range at Woomera in Australia where many British firms have bases and some of the most advanced tests have been carried out. Another large weapons testing ground is being built at Maralinga, in Western Australia.

Guided weapons contracts are awarded to industry in packaged form as weapons systems, and the parent company doing the "airframe" is responsible for the overall project and its ultimate success or failure. At present there is some friction between the electronics firms and the "airframe" manufacturers, as the latter in some cases have been setting up their own electronics departments, thereby diverting labour and contracts from the pure electronics firms. This, of course, does not apply in the case of a company like English Electric, where Marconi is already within the group to meet all requirements, while the Nelson research laboratories take care of computers, etc.

Companies known to be heading major projects are:—A. V. Roe, Armstrong-Whitworth, Bristol, de Havilland, English Electric, Fairey and Short Bros. Power plants are being provided by the Bristol Engine Company, de Havilland Engine Company, D. Napier & Son, and Rolls-Royce Ltd.

Altogether some 150 firms are involved in missile work, on materials, guidance, test equipment and power plant detail work. They include Associated Electrical Industries, Elliott Brothers, E. K. Cole, F. G. Miles Ltd., General Electric, Rotol, Sperry, Decca, Cossor, E.M.I., Kelvin and Hughes, Imperial Chemical Industries, Winston Electronics, Solartron, Goodmans Industries, H. M. Hobson, Plessey, Rotax, Venner, and Bakelite, to mention only a few.

The United Kingdom's present guided weapon effort is fivefold:

1) The intercontinental ballistic missile with H-bomb warhead, possibly atomic-powered, together with an interim ramjet bombardment missile having an atomic warhead if required.

2) One or two advanced ground-to-air weapons capable of shooting down supersonic aircraft.

3) A medium range ship-to-ship or ship-to-shore bombardment missile, probably with an atomic warhead.

4) At least two air-to-air missiles, one for intermediate use, and the other for such advanced fighters as the English Electric P.1., the Gloster *Olympus-Javelin,* and the Saunders Roe SR.53 jet-plus-rocket type.

5) An aircraft-to-ship anti-submarine weapon which will be the mainstay of Coastal Command's and the Fleet Air Arm's anti-submarine squadrons.

The British I.C.B.M. is in its early stages and is such a big project that several major firms are believed to be involved. One of these may be A. V. Roe, and if an atomic power plant is used, either Hawker Siddeley or Rolls-Royce would probably participate.

A test vehicle powered by a Napier ramjet leaves the launching ramp.

The major ground-to-air project released so far is by English Electric, with guidance by Marconi. It is capable of over 2,000 m.p.h. and has overlap boosters. Production is likely to commence in the near future for R.A.F. trials.

Bristol's are believed to be working on a ground-to-air missile using ramjet power; few pictures of the company's ramjet test vehicles have been released. They may also be concerned with the medium range surface-to-surface weapon.

The ship-to-ship or shore missile for the Navy is in the hands of Armstrong-Whitworth, with guidance by the General Electric Co. Ltd. Trials with this unit are well advanced and production should be put in hand later this year. Simulation of ship conditions for this weapon have been carried out on the "Clausen Rolling Platform" at Aberporth.

First air-to-air weapon released is the beam-rider Fairey *Fireflash* now in production for the R.A.F. for familiarization and working up. It will be used initially on a special version of the *Swift,* but later will be offered for export on the Hawker *Hunter* and other British aircraft. The *Fireflash* is some 10 ft. long and has overlap solid fuel booster rockets.

Later, the de Havilland Propeller Company's air-to-air missile is to be adopted as standard by the R.A.F. This will have a high performance and good range characteristics plus (so it is reported here) a highly sensitive infra-red heat seeking system.

A Bristol ramjet test vehicle in flight. Tandem booster rockets accelerate the vehicle to supersonic speed.

Guided missiles

Guidance Systems for Anti-Aircraft Rockets

BY DR. ING. ALFRED GERBER, ZURICH

The author, who was born on May 21st, 1912, at Langnau, Canton of Berne, Switzerland, studied engineering at the Federal Institute of Technology, Zurich, and obtained his Doctor's degree in engineering under Professor Ackeret in 1938 with a dissertation on boundary layer suction. Today he is head of the Arms Division of Oerlikon Machine Tool Works, Bührle & Co., Zurich, Managing Director of Contraves AG., Zurich and of Contraves Italiana, Rome, and a lieutenant-colonel in the Swiss Army. — The first part of Dr. Gerber's article deals in general terms with recent anti-aircraft rockets; the second, for readily understandable reasons, more specifically with his own designs, i. e., the Oerlikon rocket with Contraves beam control system. Editors.

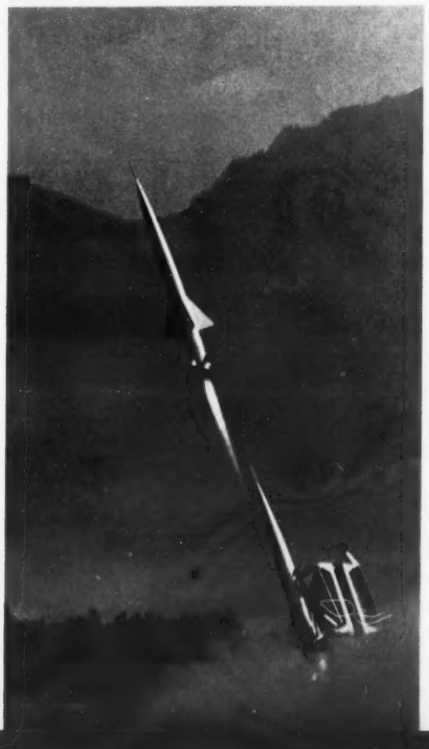
During the first five decades of its existence the anti-aircraft artillery—only a few years younger than powered flight—has had to make exceptional efforts to keep pace with the rapid development of military aircraft, especially bombers.

The first gun for use against balloons, airships and aircraft was put into service by the German Army in the spring of 1906. Anti-aircraft defence thus celebrates its 50th anniversary this year. In August 1914 the German Army entered the war with a total of 18 anti-aircraft guns (cal. 7.5 cm), some horse-drawn, some self-propelled. Four years later, to stick to the same example, it had some 50 heavy 8.8 cm anti-aircraft batteries, each equipped with a computer for calculating firing values. The new weapon was quite successful on the whole against the aircraft of those days, with speeds of up to 125 m. p. h. at altitudes of up to 10,000 ft. For example, 80 aircraft "kills" were attributed to the German anti-aircraft defences in July 1918 (figures for Allied anti-aircraft successes are unfortunately not known to me).

In World War II the anti-aircraft artillery had an incomparably more difficult task. Bomber speeds had meanwhile risen to around 300 m. p. h. and their vulnerability to gunfire had been greatly reduced through their all-metal construction. Although bomber squadrons generally attacked at altitudes of no more than 10,000 to 20,000 ft., the heavy anti-aircraft guns on the British side (cal. 7.6 and 9.4 cm) and on the German (cal. 8.8, 10.5 and 12.8 cm) succeeded in shooting down on an average only two to three aircraft per ten thousand rounds, despite constant improvements in electronic detection and fire control equipment. And when, towards the end of the war, the first jet aircraft appeared in the skies — the German Messerschmitt Me 262 and Arada Ar 234 "blitz bombers" and the British Gloster *Meteor* fighters (and later fighter-bombers) — the days of the heavy anti-aircraft gun were definitely numbered. Against speeds of more than 500 m. p. h. and altitudes above 30,000 ft.—today both values are 50 to 100% higher—the old-style "lead" anti-aircraft artillery is powerless.

The beam-guided Oerlikon anti-aircraft rocket is fired without boosters from mobile twin launchers designed for a high rate of fire (up to twelve rockets per minute for six launchers).

The first rocket has left the launcher. Gyro-stabilized in the launching phase, it initially balances on its gas stream (combustion chamber control) and then swings into the beam transmitter's coarse beam, which automatically guides it into the fine beam.



How high can an anti-aircraft gun actually fire? Roughly speaking, the *useful vertical range* of an anti-aircraft shell (expressed in *hectometres*) is approximately equal to its *calibre in millimetres*. Light 20-mm shells, fired from the ground, can be used against air targets flying at heights up to 2,000 m (approx. 6,600 ft.). Medium anti-aircraft guns of calibre 34 to 57 mm are adequate for heights up to about 4,000 m., and heavy calibre 7.5, 9.4 or 10.5 cm guns up to 9,000 m, or at the most 10,000 m (33,000 ft.).

The real problem in ground-based anti-aircraft defence, however, lies not in the shell's vertical range but in the time it takes a shell to cover the distance between the gun and the target, and consequently in the lead distance. Assuming a time of flight of, for example, 10 seconds for a heavy anti-aircraft shell and mean distances, a modern transonic substratosphere bomber will cover a distance of 10,000 ft. during this time. The anti-aircraft gunner, or his fire control equipment, would thus have to allow a lead distance of a full 10,000 ft., assuming that the target continued on the same straight line and at the same speed. And if the target's speed is still higher, and longer ranges are involved, the lead distance may be anything up to five times as long...

Now even if the bomber pilot did his utmost to help the gunner—which is not usually the case—he could scarcely succeed in steering so exactly towards the pre-calculated aiming point that he would really be hit by the shell. The aircraft banks and turns, is buffeted about by air gusts, changes speed, altitude etc.

There has been much talk in this connection of proximity fuses, which are designed to correct a "near miss". With these fuses, no direct hit is needed to detonate the shell's explosive charge. In principle it is sufficient for the shell to pass close to the target. However, in order to be effective, a conventional shell must detonate not more than about 5 m from the target, and a medium-size rocket not more than 10 to 12 m.

The foregoing amply explains why the *remote-controlled anti-aircraft rocket* will oust the

heavy anti-aircraft gun, indeed in many cases has already done so. The amazing fact that a projectile can be guided in flight must sooner or later revolutionize the whole science of ballistics. The development has been made possible by new *electronic transmission techniques*, which can keep the projectile under constant control from its launching point up to contact with the bomber. The "barrel" firing the projectile is thus extended to the weapon's full range, and the gunner merely has to make sure that the 15 to 20-km long "barrel" is constantly directed at the bomber, no matter what manœuvres the latter carries out.

It must, however, first be fully recognized that the anti-aircraft rocket is not an aircraft, but a *projectile*. As is known, the first German subsonic anti-aircraft rockets—the Henschel *Schmetterling* and Messerschmitt *Enzian*—were modelled on the rocket aircraft of that time. Each of these weapons was in principle a robot aircraft whose pilot's cockpit was replaced by remote control equipment on the ground. The same system of *radio command guidance* was of necessity retained in the German *Wasserfall* (developed at Peenemünde) and *Rheintochter* (by Rheinmetall-Borsig), both supersonic anti-aircraft rockets, although these rockets even externally resembled shells much more than aircraft and were already fitted with cruciform wings which did away with the necessity for roll stabilization.

On the other hand, both the American *Nike* supersonic anti-aircraft rocket (developed by Western Electric and Douglas) and the Type 54 supersonic anti-aircraft rocket produced by Oerlikon Machine Tool Works, Bührle & Co., of Zurich, were designed from the outset as *beam-riders*. There is, however, a basic difference between the *Nike* (max. speed Mach 2) and the Oerlikon rocket (max. speed Mach 1.8) and their guidance systems. The *Nike* is always launched almost vertically from concrete ramps and must therefore be guided on a *lead beam* to its probable point of impact, while the Oerlikon rocket can be launched at any angle of elevation between 30° and 90° from mobile twin launchers and follows the target—on a beam that moves with the latter—in a *curve of pursuit*[1]. In the former case a special fire control equipment with lead calculator (Missile Master) is needed, in the latter case it is not.

Contraves beam transmitter in position for operation (after removal of the wheel base). The two aerials (for the coarse and fine beams) are arranged co-axially and are rotated by a single motor; the whole electronic equipment is housed in the chassis.

Contraves tracking radar for automatically steering the battery beam transmitter on to the target. This equipment is also mounted on a mobile chassis.

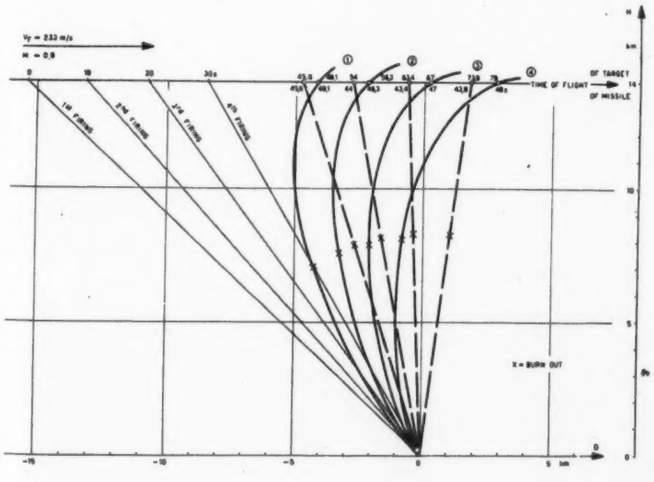
*

The above-mentioned guidance systems for anti-aircraft rockets can be classified as follows:

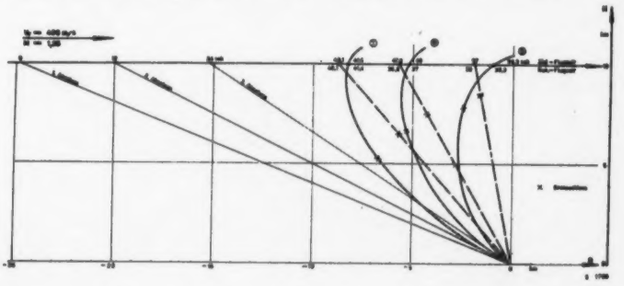
1 — *Command guidance:* rocket is guided along a roughly straight lead trajectory to the predicted point of impact with the bomber. Control is provided by deflections of the rocket's control surfaces triggered by commands (left, right, higher, lower) radioed from the ground control post to the rocket. In order to obtain the correct control commands, *two* radar sets are needed—one of which tracks the target, and the other the rocket—also a complicated computing equipment consisting of lead calculator, parallax computer, attack trajectory computer and rocket roll calculator.—*Examples: Rheintochter* (oblique launching) and *Wasserfall* (vertical launching).

2 — *Beam guidance on lead trajectory:* here, too, the rocket is guided along a roughly straigth lead trajectory direct to the predicted point of impact with the bomber. However, it responds not to command signals from the ground, but to its own, automatically produced control impulses, which keep it constantly within the electromagnetic guiding beam emitted by the control post. The rocket behaves like a hare which, caught in the headlights of a car, can escape neither to left nor to right, or, expressed in more technical terms, like an airliner taking off on instruments with its ILS receiver switched to the automatic pilot. As a rule, the beam is transmitted by a rotating dipole with parabolic reflector and received by four small dipole aerials in the rocket's wings or fins. In principle

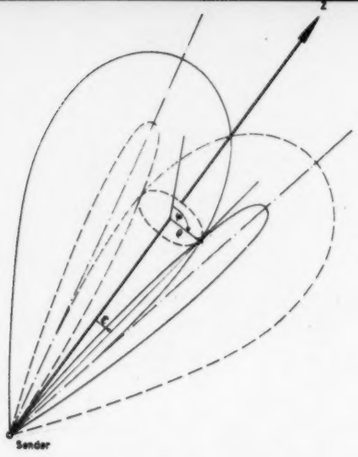
[1] A «curve of pursuit» is the track followed, for example, by a dog joining his master who is *walking forward*. The dog almost always runs in the direction in which he sees his master at any given moment, thus describing a curve.



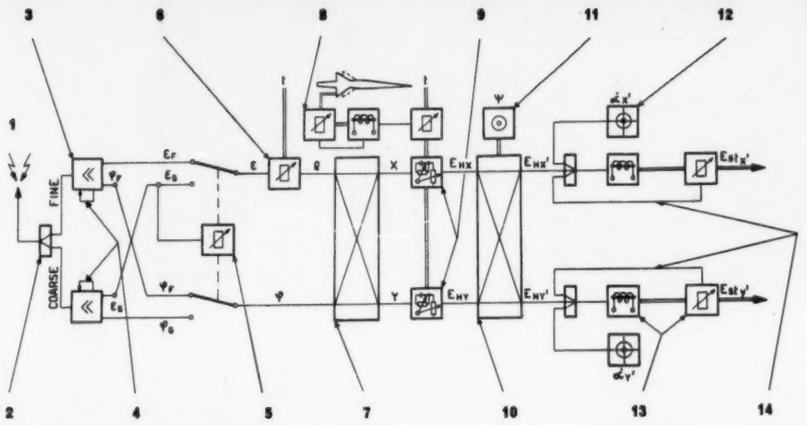
Pursuit trajectories and times for several beam-guided anti-aircraft rockets (unbroken lines) and several command-guided rockets (broken lines) each with a thrust duration of 30 secs (marked x), against a subsonic bomber (Mach 0.8) approaching at 14,000 m.



Pursuit trajectories and times for several beam-guided anti-aircraft rockets (unbroken lines) and several command-guided rockets (broken lines) each with a thrust duration of 30 secs (marked x), against a supersonic bomber (Mach 1.35) approaching at 10,000 m.



Orienting the Oerlikon rocket in the beam: angular deviation ε is determined from the amplitude modulation, and orientation angle φ from the phase difference in the frequency modulation of the signal received in the rocket. Distance ρ is obtained from angle ε and the rocket's flight time.



Schematic diagram of the airborne equipment for the Contraves beam guidance system: 1 – aerial; 2 – frequency separation; 3 – separation of amplitude and frequency modulation; 4 – amplifier gain control; 5 – coarse-fine switch; 6 – transformation of conical into cylindrical coordinates; 7 – transformation of polar into cartesian coordinates; 8 – wing displacement servo system; 9 – computing amplifier; 10 – transformation into missile-fixed coordinates; 11 – gyro to control roll position; 12 – pitch and yaw control by fixed gyro; 13 – electro-hydraulic servo system; 14 – position indicator.

it can sweep any sector, provided obviously that it is mechanically possible for the rocket to follow it. The correct lay of the beam in relation to the lead point is calculated by a computing system similar to that used in the command system. However, only one radar equipment is needed, which remains constantly directed at the target.—*Example: Nike* (approximately vertical launching).

3 — Beam guidance on "curve of pursuit": the rocket remains in the axis of the beam, which is always directed at the target, so that collision takes place in spite of any evasive action the target may take. The three points—beam transmitter, rocket, target—always lie in a straight line, and the rocket follows an upward curving trajectory. Although it always remains in the beam, it rarely flies in the direction of the beam but sets its longitudinal axis roughly on to the point of impact . . . a kind of "cost-free" lead determination without calculations. For this purpose target tracking radar and beam transmitter are set up in parallel in azimuth (turning movement) and elevation (sweeping movement), as if they were practically speaking a single unit. Actually, however, they can be up to 800 m apart. Complicated lead calculations are not required in this system, a parallax computer (to allow for the difference in position between the target tracker and the beam transmitter), a coordinate transformer and a number of correcting units sufficing.—*Example:* Oerlikon Type 54 (oblique or vertical launching).

*

The trajectories followed by the rockets in these three systems will now be examined more closely for the following two cases:

1 — defence against a subsonic bomber (Mach 0.8) approaching at 14,000 m (approx. 46,000 ft.);

2 — defence against a supersonic bomber (Mach 1.35) approaching at 10,000 m (32,800 ft.).

As radio command guidance (Method 1) and beam guidance on a lead trajectory (2) differ only in technical details, but not in tactical principles, they are combined in the two diagrams. The corresponding rocket trajectories are shown as broken straight lines. The rocket used to illustrate the system of beam guidance on a curve of pusuit is the Oerlikon Type 54, which has the following characteristics:

Overall length	approx. 6 m (19 ft. 8 ins.)
Diameter	approx. 0.4 m (15¾ ins.)
Span of cruciform wings	approx. 1.4 m (4 ft. 7 ins.)
Launching weight	approx. 375 kg (825 lbs.)
Warhead	approx. 20 kg (44 lbs.)
Rocket motor thrust	1,000 kg (2,200 lbs.)
Specific consumption	5 kg/secton
Duration of thrust	30 secs
Mach number at burn-out	1.8
Range with full guidance	15—20 km (9—12½ miles)
Combat altitude	3,000—15,000 m (10,000—50,000 ft.)
Launching angle	10°—90°

Other features: nitric acid plus diesel oil power unit, ignited by triethylamine and xylidine; feed is by compressed nitrogen (300 kg/cm²); combustion chamber control, combined with aerodynamic control through fins; proximity fuse; training rocket splits into two parts in front of the wings and descends on two parachutes; wrapped-sheet light alloy body with Araldit bonding; wings of sandwich construction and displaceable in fore-and-aft direction (to compensate for changing centres of gravity and pressure).

Pictures show the trajectories followed when several rockets are launched at regular intervals against the same target. Here, the advantage of *Method 3* is clearly illustrated, since several rockets can be "fed" into the same beam, whereas with the lead system (methods 1 and 2) a separate control post or beam transmitter is required for each rocket. An Oerlikon anti-aircraft battery consisting of six twin launchers and a target tracking radar with coupled beam transmitter can, for example, fire up to twelve rockets a minute.

In the case of the enemy approaching at 46,000 ft., the first rocket leaves the launcher at the moment (zero time) when the target is about 15 km from the battery—measured horizontally. The others follow at double the minimum interval, i. e., every ten seconds. The first rocket catches up with the bomber within 48.1 seconds; the second, starting off 10 seconds later, within 46.3 seconds and so on. By comparison, rockets flying on lead trajectories would save a little time, but the lead distances would average 10 km!

In the second example—a supersonic bomber at 32,800 ft. with a Mach number of 1.35—similar conditions apply. In both cases it can be clearly seen that the curvature of the rocket trajectories increases after the rocket motor burns out, a consequence of the rocket's diminishing speed. It should be noted here that, thanks to its control surfaces, the Oerlikon rocket remains fully controllable even after burn-out (at Mach 1.8), until speed falls to Mach 1 again.

*

How a beam guidance system coupled direct to the target tracker works is also explained with the Oerlikon-Contraves method as an example.

The control post of the rocket unit consisting of three batteries (each with a maximum of six twin launchers) is equipped with a target acquisition radar, and each battery in addition has its own radar tracker. The targets detected by the unit are assigned to the various batteries and tracked by the latter in their own radar. The tracking radar automatically controls the beam transmitter mounting and the twin launchers, both of which have full sweep (nearly 180°) in elevation and 360° in azimuth.

The beam transmitter emits a coarse and a fine beam, both on ultra high frequencies; the former has an included angle of 25° and the latter of 3°. The coarse beam serves to "catch" the rocket after launching and then guides it into the fine beam. The two aerials are arranged co-axially and are rotated by a common motor. The speeds and accelerations of the beam's movements are limited by a computer in such a way that, when the battery radar rapidly changes target, the beam can move only as fast as the rocket can follow it.

The rotating UHF beam produces a varying signal in the rocket's aerials only when the

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rocket is outside the beam's axis of rotation (see diagram). A frequency filter first separates the signals from the coarse and fine beams, which arrive at the same aerial system. The amplitude modulation produced by the rocket's angular deviation from the beam's axis of rotation (ε) and displaced by the phase position (φ) is then separated from the frequency modulation, which is synchronous with the aerial rotation. A special relay switches over to the fine beam once the coarse beam modulation falls below a given value. Finally, electronic computers in the rocket transform the conical coordinates (ε and φ) into cylindrical coordinates (ϱ and φ), for which purpose they must know the rocket's distance from the transmitter. This distance is calculated with sufficient accuracy from the rocket's time of flight, via a time mechanism. But this is not all; the cylindrical coordinates (ϱ and φ) must finally be transformed into cartesian coordinates (x and y), first into beam-movement fixed coordinates and then into missile-fixed coordinates, i. e., with allowance for the rocket's turning about its longitudinal axis as determined by a gyro. The final cartesian coordinates are assessed and transformed into impulses which are fed to the electro-hydraulic servos for the combustion chamber/rudder controls. After burn-out the wings are moved forward by 15 to 25 cm (6 to 10 ins.)—to improve controllability with centre of gravity in its most forward position—by means of the same time mechanism as mentioned above, via a potentiometer with electro-hydraulic servo motor.

With the aid of this equipment on the ground and in the rocket it is possible to engage any known bomber within the range of the rocket battery (15—20 km). Slight errors in the guidance system are compensated by the proximity fuse. In addition, it is possible to fire at an oncoming enemy.

*

Finally, a brief summary of the demands made on modern anti-aircraft rockets and their guidance equipment:

1 — adequate speed at burn-out to ensure effective use against supersonic aircraft; if necessary with the aid of take-off boosters.

2 — oblique launching at any desired angle, to economize on guidance equipment and computers and to permit use against oncoming targets.

3 — Beam guidance on a curve of pursuit, to ensure contact with the target regardless of the latter's manoeuvres. Proximity fuse for near misses.

4 — High rate of fire and possibility of rapid change of target.

5 — Recoverability of training rockets.

6 — Mobility of rocket batteries to enable sites to be changed rapidly. For this reason concrete emplacements are unsuitable. In addition, no component—launcher, tracking radar, beam transmitter—should weigh more than 4 tons, and each must be capable of immediate conversion from towing to firing position.

Environmental Considerations of Space Travel from the Engineering Viewpoint*

BY A. M. MAYO, DOUGLAS AIRCRAFT COMPANY, INC., EL SEGUNDO, CALIFORNIA

New problems are being generated by man's increasingly active encroachment toward the fringes of space. One of the foremost is the design of the crew space, as flight in space will impose new physiological and psychological stresses on top of the expected operational demands of the crew members. Therefore, the location and size of the occupied area should be determined with full cognizance of the functional and environmental requirements of the crew. These relatively fixed human requirements must of necessity take priority over the comparatively flexible requirements of equipment.

Vision and time-distance problems

As speed increases it is necessary to make decisions resulting from visual information from increasing distances, in order for man's time constant to be satisfied. Increased altitude also dictates the reception of visual stimuli from greater distances. These fundamental visual problems immediately generate a requirement for improved electronic aids to provide information over great enough distances to allow the human operator time to make effective decisions.

Although progressively less of the required visual information can be obtained from direct outside observation, man's past psychological conditioning will probably for a long time dictate the incorporation of transparent areas in manned aircraft.

Time must increasingly be recognized as a fundamental quantity, and distance a subordinate variable, if we are to realize the maximum potential of the man in the system. *Figure 2* shows that certain types of control functions must be handled by devices capable of sensing and reacting to changes in much less time than can a human being.

Fig. 1: Drawing of a piloted experimental supersonic aircraft for research flights to the limits of the earth's atmosphere.

Temperatures

Since the temperature rise of a molecule of gas on becoming rapidly accelerated to the speed of the aircraft is proportional to the square of the speed (see *Figure 3)*, it is not too hard to understand why temperature problems already solved in present day aircraft can become serious unsolved problems for higher speed flight within the atmosphere. The fire path of a meteor is but one example of the devastating effect very high velocity within the earth's atmosphere can have on materials normally considered heat resistant. Fortunately, temperatures encountered at extremely high altitudes cease to have the same meaning in terms of actual heat transfer as the same temperatures at sea level, even though each particle has energy equal to that at sea level. As altitude increases the number of particles decreases so greatly that the normally felt heat transfer by means of conduction and convection becomes negligible, with radiation assuming the predominant role in the outer fringes of the atmosphere. This effect is illustrated in *Figure 4.*

Figure 5, based on data from References Nos. 4, 5 and 6, shows that the primary temperature control of a flight above the atmosphere becomes a function of stored energy and

* Paper read to the Aero Medical Association, Chicago, Ill., April 16-18, 1956

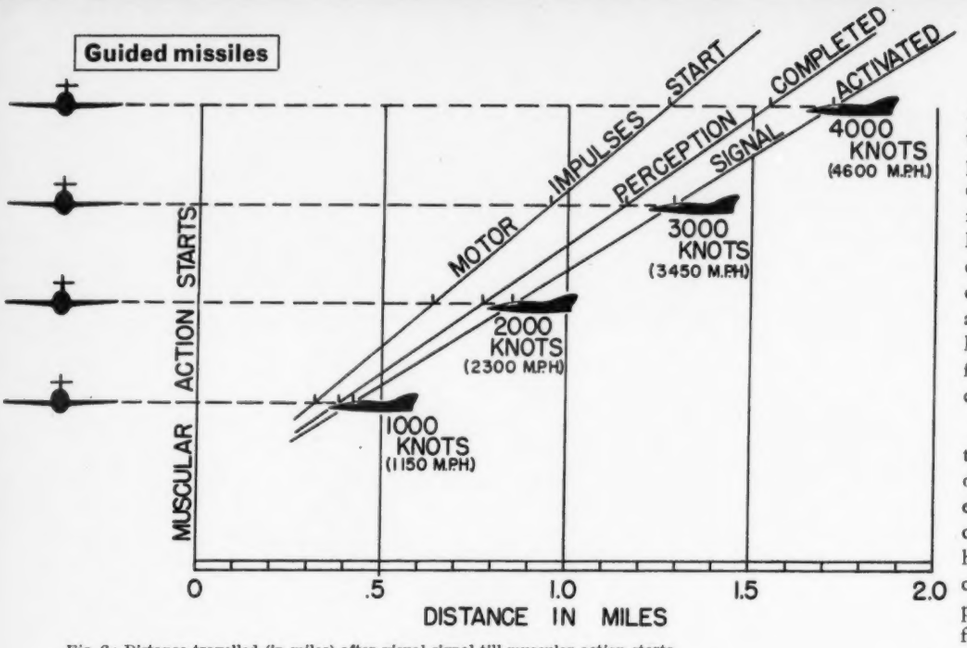


Fig. 2: Distance travelled (in miles) after visual signal till muscular action starts.

of radiant heat transfer. For flights in which re-entry to the atmosphere is required, structure temperature control becomes extremely critical. The external portions of the aircraft will need to be designed in such a manner that substantially all of the heat generated on the craft's surface in using up the terrific kinetic energy and gravitational potential energy of the craft can be dissipated by radiation and molecular rebound. The aerodynamics of this craft must be such that this heat transfer will be accomplished within the temperature limitations of the structure to prevent the craft from falling into the category of a vaporizing meteor.

For flights up to roughly 70,000 feet, various modifications of the air cycle and ram air cycle refrigeration system will probably be usable, with the ram cycle systems finding their applications mostly with ramjet engines where a source of high compression ratio air will not be available. At altitudes substantially above 70,000 feet, the air cycle refrigeration systems are so ineffective that storage or radiant temperature control systems will become necessary. Cooling by means of the evaporation of liquid oxygen in conjunction with the use of substantial thermal insulation may be practical for short flights. Radiant heat transfer for temperature stabilization may be visualized by considering the fact that greater or lesser proportions of dull (high emissivity) surface can be presented to the direct rays of the sun as against the proportion of shiny (low emissivity) surface. With greater portions of dull surface toward the sun and the shiny surface away from the sun, the temperatures of the craft will tend to increase. The temperatures will tend to decrease when the shiny surface is presented to the sun.

Pressure

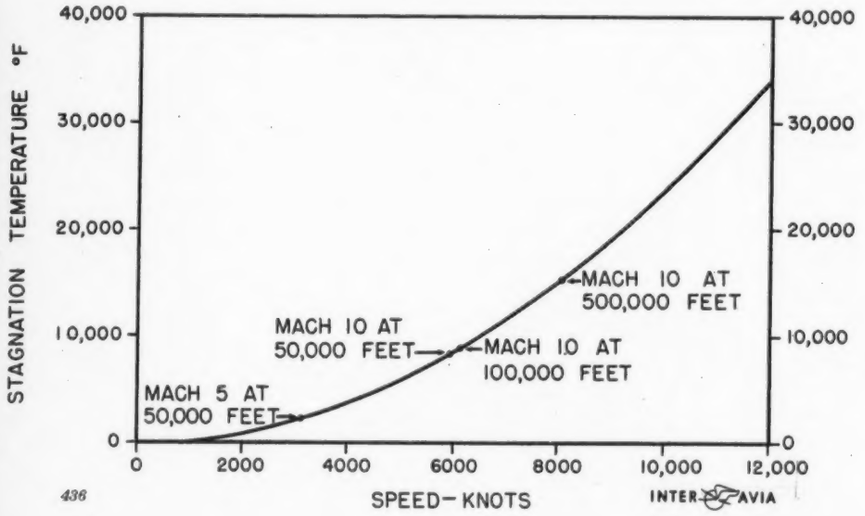
Mountain climbers and later the early balloonists experienced some of the problems involved in performing physical tasks under conditions of reduced pressure. Here the important physiological result was that of hypoxia. At increasing altitudes the continuous reduction of pressure gives rise to additional physical problems such as "bends and chokes" and eventually to excessive swelling due to evaporation of liquids within the body. These later troubles occur even in the event of proper compensation of oxygen. At very high altitude counter pressure is also required to maintain a sufficient partial pressure of oxygen in the lungs in order that the oxygen can be transferred through the lung tissues to the red blood cells, then to the using cells.

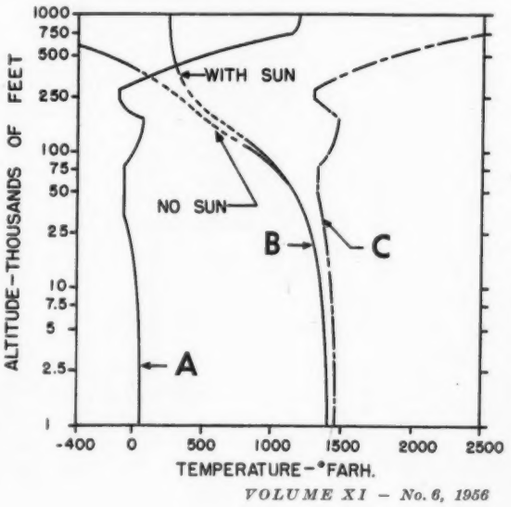
These problems together with those of maintaining proper air composition (by elimination of impurities and toxic gases) can and are being effectively handled in pressurized cockpits by compressing the outside air to ratios sufficiently high to allow both for cooling and workable cockpit pressures. This approach appears practical only to roughly an altitude of 70,000 feet because of the radical increase in problems associated with the compressing and cooling of the rarified air at higher altitudes.

For short duration flights above 70,000 feet, a simple storage system utilizing liquid oxygen can probably do a satisfactory job of both cooling and pressurization. The presence of such small amounts of carbon dioxide, water vapor and excreted body gases as would occur could undoubtedly be tolerated for short periods of time.

Self-contained pressurizing and air purification systems needed for extended flights above the atmosphere will become increasingly difficult to provide. Much of the technique developed for use in submarines will probably be useful for flights of intermediate duration. For very long duration flights, much more work on the chemistry of air regeneration to provide, essentially, a hermetically sealed balanced environment will be necessary. As the outside ambient pressures become very low compared to cockpit pressures, an explosive loss of pressure, as in the case of a damaged cabin, or even a slow loss would present a very serious problem. Until the cockpit structure and pressuri-

Figs. 3 and 4: Left: stagnation temperature (in degrees Fahrenheit) plotted against speed (in knots). – Right: temperature (in degrees Fahrenheit) of a body travelling at 2,610 knots plotted against altitude (in thousands of feet). A = atmospheric temperature; B = skin temperature; C = temperature of boundary layer.





zation system can be developed to a point of reliability equal to that of the basic structure components, some sort of a pressure safety equipment will be a realistic need. One approach to this type of equipment would be the provision of a pressure suit designed to be as light and comfortable as possible for use in its normal unpressurized condition, even to the point of allowing for substantial loss of comfort and mobility during the emergency. The philosophy of this equipment would then be comparable to that of a parachute, where actual use may never occur during the entire flying career of a pilot but would be highly essential in case of a pressure emergency. In the case of a commercial transport flying at altitudes so high that it is impractical to dive to a safe altitude upon accidental decompression, the safety of the passenger would rest primarily with the design engineer, who must provide pressurization of an order of reliability consistent with that of the basic aircraft structure.

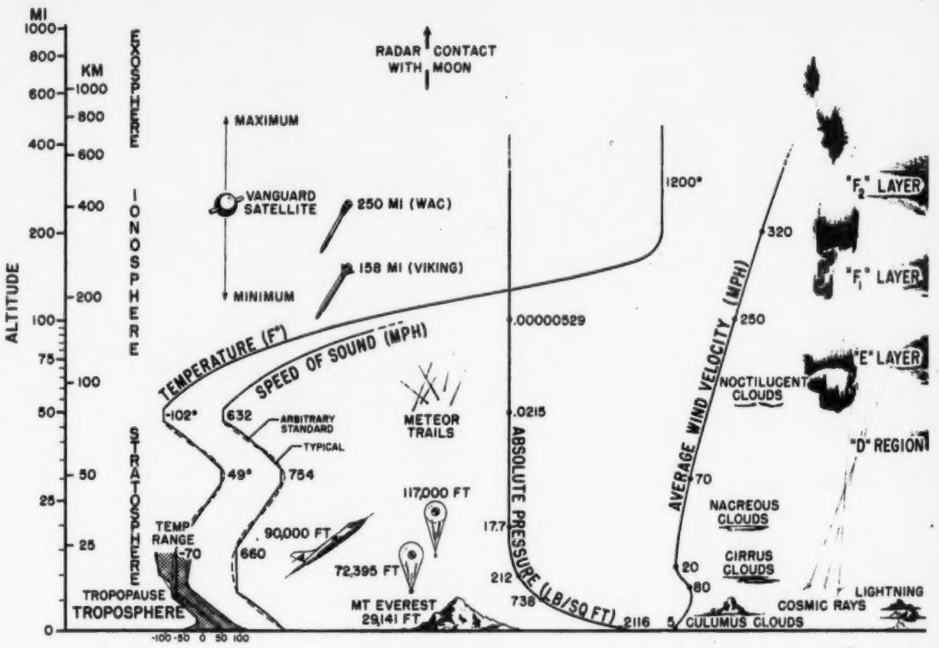


Fig. 5: Change in atmospheric conditions with increasing altitude.

Acceleration

As the present type of aircraft is improved for higher altitude flight, it is probable that turning and maneuvering accelerations of a relatively low order of magnitude but of substantial duration will become important to the engineer.

As extremely high thrust rocket engines are utilized for manned vehicles, it is likely that conditions will arise where the acceleration tolerances of man will be an important limitation. During the take-off phase, thrust-time relationships must be controlled to values allowing the crew to perform the assigned tasks. The problem of re-entry into the atmosphere will be even more demanding with respect to acceleration control. Presently available studies indicate that relatively small errors in control during re-entry can impose very large acceleration loads on the craft and the crew.

Another area of important acceleration studies includes those conditions in which either the direction or the magnitude of acceleration is changing at a rate faster than the reflexes of the human being. It is likely in certain emergency conditions that such changing directions and magnitudes of acceleration might introduce problems under which control and even operation of emergency systems would become virtually impossible. Some very good work on these areas has been done by the Navy's Aviation Medical Acceleration Laboratory. Even so, additional work is necessary to define man's limitations thoroughly under these conditions.

Once in orbital flight the problem of weightlessness or zero gravity state will be of considerable interest to the designer. While it appears relatively easy to provide a certain level of artificial gravity, much remains to be learned about the detail effects of the weightless state on a human being. While Haber and others have done much very clear thinking on the subject of the weightless state, very few data are available based on prolonged experimentation at or near the zero gravity condition. Much conjecture exists concerning the levels of G and the time of indoctrination necessary to overcome the disorientation effects of the removal of our normal gravitational environment.

Figure 6 gives an indication of acceleration-time tolerances without being sufficiently precise to show possible changes caused by the difference in fundamental body systems affected by the stress at different levels. Neither does this curve indicate reductions in tolerances as a function of the rate of change of application

Fig. 6: Acceleration of the human body plotted against direction and duration of acceleration. In the grey-shaded zone the theoretical tolerance is greatly reduced in the case of higher rate of acceleration.

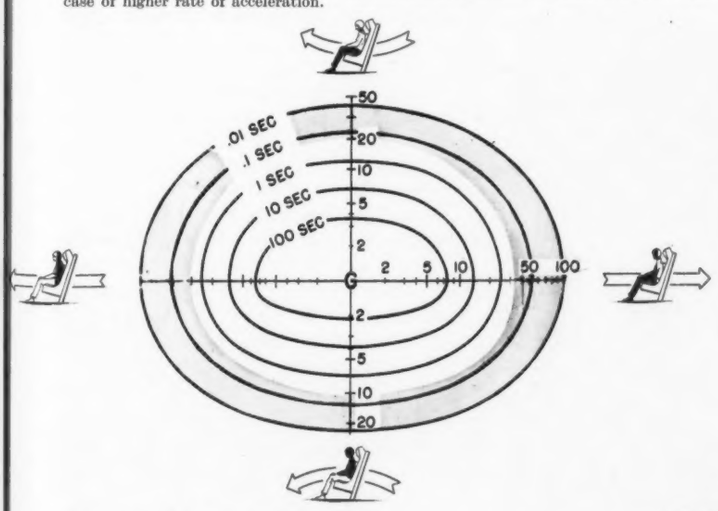
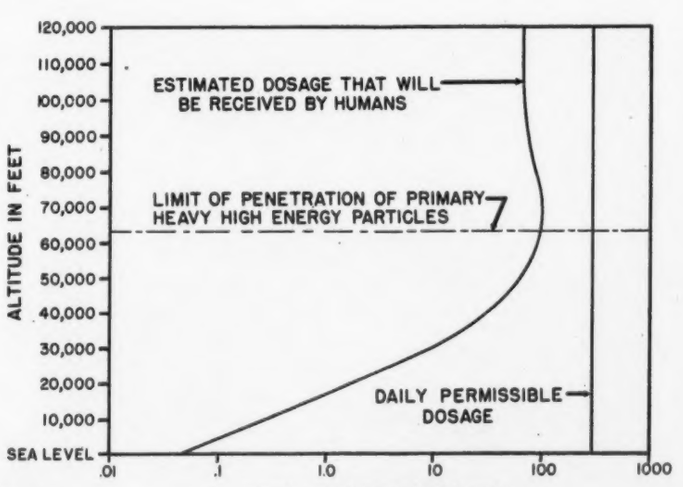


Fig. 7: Daily dosage of cosmic rays (in millirems) to which human body is exposed, plotted against altitude (in feet).


ESTIMATED DOSAGE THAT WILL BE RECEIVED BY HUMANS
LIMIT OF PENETRATION OF PRIMARY HEAVY HIGH ENERGY PARTICLES
DAILY PERMISSIBLE DOSAGE
ALTITUDE IN FEET
SEA LEVEL
DOSE—MILLIREMS PER DAY

of the acceleration. While a substantial amount of good work has been done giving certain combined values of time at G and rate of change of G limitations, work still remains to be done in indicating the effects of high rate of onset of acceleration at various levels of G and time. It seems logical, for example, that low levels of G could be applied at fantastically high rates without serious effect and that the rate of onset could be sharply limiting at higher values of G. Additional aeromedical data and physical studies are needed to provide usable objective information covering conditions of rapidly changing acceleration.

Radiation

Even though many of our best informed physicists and biologists now tend to be optimistic, no one can categorically state that serious biological radiation damage will not result from extended flight in free space. Solar ultra-violet radiation without the atmosphere's protective influences would in itself be a primary hazard except for the fortunate fact that it can be easily excluded by relatively thin layers of protective material. Present indications are that solar x-rays also will present a relatively unimportant problem. This leaves the cosmic particles and other heavy ionizing radiations as major worries. No practical approach toward shielding against these particles is yet available. Present test data show that ionization from certain heavy particles is still increasing after penetrating to the center of a two foot diameter lead sphere. This leaves as the most likely present approach one of shielding against only the ultra-violet, soft x-ray and other low penetrating power radiations and leaving relatively unimpeded the path of high energy particles, thus keeping the width of the high energy ionizing tracks to a minimum. *Figure 7* shows values of present and permissible radiation doses and expected intensities versus altitude. These data are among the best now available, but do not cover all possible effects of heavy cosmic particles and their secondary reaction.

Meteor collision

With probable meteor velocities in the order of magnitude of 150,000 to 250,000 feet per second, it can be seen that energies, per unit mass, approximately 10,000 times that of ordinary gunfire projectiles will be probable. This would indeed be an unfortunate situation except for the fact that the vast majority of meteor particles are extremely small. From data collected by Whipple it appears that an aircraft presenting 1,000 square feet of area projected normal to the earth might fly for approximately '00 years before having its $^3/_8$" simple dural skin penetrated by a meteor. Whipple has suggested that a structure designed for better utilization of material might provide a thin outer buffer skin to cause an explosion of the meteor particles (explosion is likely on hitting a thin member because of the extremely high ratio of kinetic energy to momentum) and thus spread out the resulting smaller particles over a larger area of the primary skin structure. Thus more skin area would be brought into the function of resisting penetration, and the resulting weight of this double skin structure could be considerably less than that of a single skin structure.

With this in mind, it can be seen that even though no reasonable method for protection against a direct hit by a large meteor exists, the problem is not one to merit excessive worry since it can be classed in the probability category of being struck by lightning or one of the numerous secondary hazards of everyday living. A more real problem might be the sand blasting or erosion effects of numerous but fantastically small meteorite particles on observation windows or other transparent surfaces. It appears likely in fact that in order to preserve the transparency of observation ports some type of cover might be a requirement.

Fig. 8: The cockpit capsule of a high altitude research aircraft after separation from the fuselage. A number of parachutes opening successively would bring the capsule safely down to earth. Control fins unfolded from the rear of the cabin stabilize the fall and enable flight path corrections to be made.

Escape

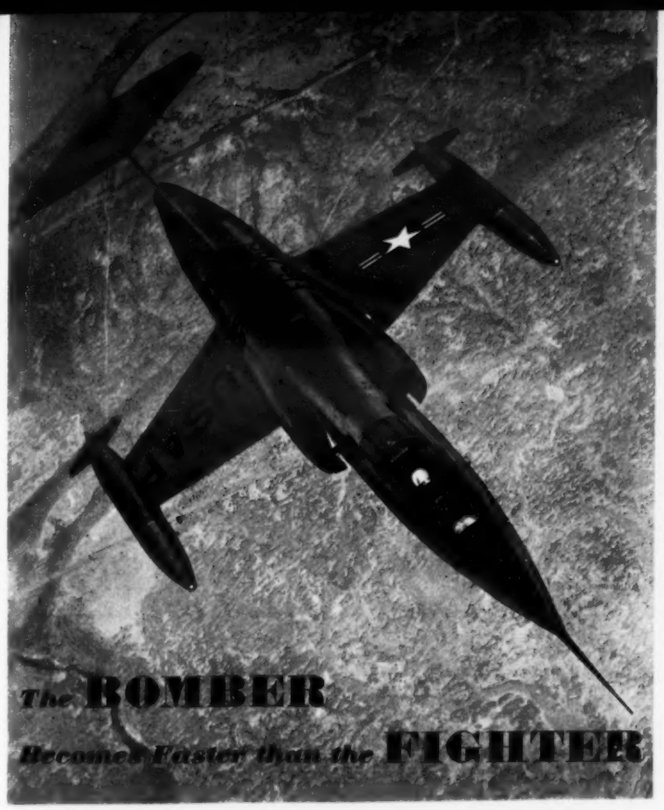
The question of how much emphasis should be placed on getting people safely out of damaged or burning aircraft has presented itself since the very beginning of flight. The means of accomplishing emergency escape are perfectly possible from the engineering standpoint. An escape capsule of the type shown in *Figure 8* appears capable of performing the required functions of environmental and acceleration protection at coming intermediate altitudes. In certain types of space craft it appears likely that the final stage of the craft devoid of its fuel and other fire hazards might well be designed to serve the combined function of normal flight and escape vehicle.

Combined stresses

The difficulty of gathering and cataloging physiological data has made it necessary to concentrate on getting information on the effect of single stresses on subjects rather than trying to evaluate the complex interactions of the more realistic conditions of combined physiological stresses. Because of the way in which these data have been made available to engineers, it has not been uncommon for the engineer to make the error of assuming that a man should be able to withstand the maximum values of several individual stresses simultaneously. The fact that this assumption is dangerous can be illustrated by noting that some of these stresses have a direct additive effect on the same body system and others individually affect more than one body system. One example of this problem is illustrated by combining a condition of 10,000 foot cockpit altitude with the carbon monoxide concentration of .01 per cent (both permissible under current flying regulations). This simple combination can reduce the oxygen saturation of the arterial hemoglobin to a value as low as 77 per cent and thus cause a very substantial reduction in efficiency. When simple combinations of stresses such as this can show substantial effects, it is not surprising that these combinations of conditions with such additional effects as repeated accelerations from pull-outs and "morning after", together with the normal psychological and physiological stresses of flying, can at times end up in fatal accidents.

Conclusions

The basic medical, physical and engineering data for manned flight in free space, while still inadequate, are rapidly being assembled. Progress to date has been made possible by the combined effort of people in practically every branch of science. As the day of manned space flight is more closely approached, a drastic increase in the amount of effort will be needed to answer the increasingly detailed questions incident to actual design fabrications and operation of the manned space craft.



The Lockheed F-104 invalidates the theory of the fighter's superior speed.

The few details of the Lockheed F–104 which have just been revealed have set aerodynamicists and engine designers feverishly to work. Faster in both level flight and climb, lighter, more powerful, more advanced in design and construction than anything hitherto seen, Lockheed's "bi-sonic" fighter forecasts a whole new generation of military aircraft which will no longer become "stuck" in the transonic range. Military staffs and strategists also should be at least as impressed by the U. S. Air Force's new machine as the aircraft experts. Two statements made by Lockheed spokesmen during the "roll-out" at Palmdale on April 17th should shake the foundations of classical aerial strategy. The first was that, in addition to its normal armament—details of which have not yet been made public—the Lockheed F–104 can carry a number of external weapons, including tactical A-bombs. The second: the F–104's range is comparable to that of jet fighters already in service.

The U. S. Air Force thus has an aircraft that is very much faster than the fastest interceptor otherwise in existence, and capable of carrying beneath its wings or fuselage a bomb with a destructive power greater than that wielded by several thousand 1944-type bombers. There is just one limitation: this tremendous power of destruction, which could be carried at a speed almost twice that of sound, could be applied only within a relatively short distance of the bases of departure. The immediate consequences of the weapons system which Lockheed has just created are revolutionary enough. Within a strategy applied to short distances—say, for the defence of territory within about 300 miles of the enemy's source of air power—the old theory that the bomber must be heavier, larger and slower than the fighter must be discarded along with other concepts outdated by technical evolution.

It is, incidentally, quite natural that the aero-nuclear combination should destroy many cherished ideas. The first sign of this revolution was seen several years ago. When the U. S. Army announced that it had developed and tested an atomic cannon firing 280-mm shells, each with a destructive power equivalent to several thousand tons of TNT, it provided the first demonstration of an unexpected reduction in the size and weight of the nuclear explosive and its "package". Even if the bomb which the Lockheed F–104 carries is twice as heavy and twice as big as the 280-mm shell, it will still be lighter and less bulky than the interceptor's present armament (20 or 30-mm cannon). In theory then—and over a range equal to that of an interceptor—the "bomber" should be lighter, smaller and hence faster than the interceptor.

It will be argued that the interceptor, too, will progress, beginning by replacing its conventional heavy, bulky internal armament with air-to-air guided missiles. If it carried only one of these missiles, it would—other things being equal—probably have characteristics approaching those of the A-bomb carrier it is intended to intercept. However, the bomb falls by gravity, while the missile has to be propelled, guided or even "attracted" by its prey. It follows that the bomb has the advantage of simplicity over the missile, and consequently of weight and size. If the interceptor were armed with two air-to-air missiles, it would be penalized in weight and speed in relation to the same aircraft carrying a single bomb. And if the destructive effect of an air-to-air missile is compared with that of an A-bomb, the "bomber" with one bomb will be found to be superior to the fighter with one missile.

The nuclear explosive has thus modified a speed relationship that is as old as military flying itself. Most of the conditions have now been assembled that will enable the bomb carrier, the aircraft that is still called a "bomber", to be faster, over short distances at least, than the aircraft whose mission it is to intercept it and shoot it down and which is still called a "fighter". The "miniaturization" of offensive weapons thus renders it almost impossible to make a clear distinction between the two categories. The bomb has become negligible in weight and drag, and the aircraft designer is now limited only by fuel requirements (range) and aiming problems (to ensure independence of atmospheric conditions). The fighter designer encounters the same problems and cannot hope to do better than equal the aircraft carrying a single A-bomb, at any rate where short-range operations are concerned.

The Lockheed F–104 is a symbol *par excellence* of the new similarity between the characteristics of two aircraft categories that have hitherto always differed not only because they performed different missions but because each appeared unbeatable in its own tasks. Over short ranges it is both the most formidable of bombers and the fighter with the highest performance. It would certainly be interesting to follow an engagement in which the attackers were F–104s carrying a bomb and the defenders F–104s with air-to-air missiles. If such an engagement took place near the attackers' bases, it is doubtful whether the defenders could record many successful interceptions.

Applying this development to present world strategy, it is obvious that:

1. The bomb-carrying F–104 would have to be the offensive weapon of the Western forces stationed near the Iron Curtain, or that its Russian counterpart would have to be deployed in such a way as to threaten Western Europe's vital military and population centres, and

2. The F–104 armed with air-to-air missiles or cannon (if still armed with the latter in its interceptor version) should be used to defend targets at a greater distance from the Iron Curtain; here the fighter would regain its classic advantages over the bomber, which, because of the fuel it must carry in order to cover the longer route, would be heavier and slower. Conversely, and for the same reason, the Soviet reply to the F–104 interceptor version could certainly score some success against the West's long-range formations, whose kerosene load also makes them heavier and slower.

The date when the first operational unit of Lockheed F–104s will be formed has not been revealed. Still less is it known whether or when such units will be sent to Europe. However, even this "wonder aircraft" is hampered by technical limitations. It surpasses all other machines in performance when in its own element, but in order to get there and return it still needs long runways that are difficult to build in sufficient numbers and are highly vulnerable.

The Russians have recently proved that they are well advanced in aircraft development. They are in the lead in the power of their engines. They are close on the heels of the best American design offices in the design of short, medium and, latterly, long-range equipment. It is quite possible that a Soviet reply to the Lockheed F-104 may soon appear in the skies of Tushino. The question would then arise of how to equip a defensive organization designed to halt aircraft capable of flying at 1,200 m. p. h. and of dropping atomic bombs 200 or 250 miles from their bases. The attackers would be in the air space to be defended for about ten minutes—minus the four or five minutes they need to reach their operating altitude. And if it happened—as Field Marshal Lord Montgomery has so often maintained —that the attack came as a surprise, it is easy to imagine the weakness of any defensive system not based on particularly efficient surface-to-air missiles.

What's in the Air?*

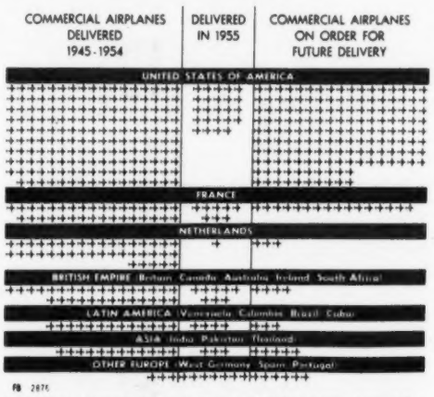
AIR TRANSPORTATION

● **A five-year plan** for a modernized Federal air traffic control system designed to keep pace with the requirements of the jet age has been prepared by the U.S. Civil Aeronautics Administration. The far-reaching programme, submitted to Congress in January by Secretary of Commerce Sinclair Weeks, involves the expenditure of $246,000,000. Radar of the short-range surveillance type will be introduced at 44 additional airports; long-range radar with direct pilot-controller communication at 24 additional air route traffic centres. A new device known as a radar beacon will be set up at 133 locations, and 20 airport surface detection equipment radars to control ground movements at congested terminals are planned. Other equipment and facilities proposed include 40 additional airport traffic control towers, 383 VHF omni-directional radio ranges (VOR) with associated distance measuring equipment, 28 instrument landing systems, 49 standard approach lighting systems, 106 lead-in lighting systems, and sequenced flashing lights at 32 high intensity approach light installations. Finally, there will be facilities to provide high altitude control and nation-wide coverage of airways down to 700 feet with navigation aids.

● **A "Near-Collision" reporting programme** for pilots has been announced by the U.S. Civil Aeronautics Board. The object is to find out from every pilot who experiences a near-collision incident as much as possible about the conditions and circumstances connected with the case. All reports will by anonymous and no signature or identification of aircraft is required. To facilitate its survey, the Board has printed a stamped, self-adressed questionnaire for quick and easy reporting. The poll will be confined to the Continental United States and adjacent oceanic waters.—According to the findings of a special Government advisory group there are, on an average, four near-collisions a day involving the airlines.

● **A network of six heliports** in the New York metropolitan area is envisaged in a plan prepared by the Port of New York Authority: two major heliports at 30th Street and the Hudson River and on the East River at 42nd Street, and four smaller ones in the Battery area, on the Brooklyn waterfront, on Staten Island and in Newark. The project for the Hudson River heliport has already been approved. Construction will begin as soon as an agreement is reached between the City Department of Marine and Aviation and the Port of New York Authority on the lease of the sites selected.—Helicopter services are expected to become so popular during the next twenty years that 6,000,000 persons will travel by them annually in the New York area, said Thomas M. Sullivan, Chief, Aviation Planning Division of the Port of New York Authority. He added that the first projected heliport on the Hudson should be used by 1,000,000 persons annually in the next ten years.

These five men played a leading part in the engineering development, designing and flight testing of the Lockheed F-104A *Starfighter* supersonic fighter. Left to right: R. L. Thoren, chief of engineering flight test, Herman R. "Fish" Salmon, chief engineering test pilot, Clarence L. Johnson, Vice-President for Research and Development, James Hong, chief of the Aerodynamics Division, and William P. Ralston, project engineer.


COMMERCIAL AIRPLANES DELIVERED 1945-1954
DELIVERED IN 1955
COMMERCIAL AIRPLANES ON ORDER FOR FUTURE DELIVERY
UNITED STATES OF AMERICA
FRANCE
NETHERLANDS
BRITISH EMPIRE (Britain, Canada, Australia, Ireland, South Africa)
LATIN AMERICA (Venezuela, Colombia, Brazil, Cuba)
ASIA (India, Pakistan, Thailand)
OTHER EUROPE (West Germany, Spain, Portugal)

Lockheed Aircraft Corporation is still the biggest supplier of airliners to non-American airlines. In 1955 it delivered 31 *Super Constellations* valued at $ 60,000,000 to eight foreign airlines.

● **Scandinavian Airlines System** and the three independent Swedish operators, Airtaco AB, Stockholm (owned by the Bonner publishing house), Transair AB, Stockholm, and Aero-Nord AB, Stockholm (controlled by the Swedish Trade Unions), are planning jointly to form a new company for Swedish domestic operations and charter traffic. Its main activity will be distribution of daily newspapers to all parts of Sweden. In addition, it will handle charter traffic, especially for travel agency trips from Sweden to Switzerland, Spain and Italy. Final plans are expected to be worked out in the autumn.

● **New B.E.A. Chief Executive** is Anthony Horace Milward, 51. Milward originally came from the textile trade, served as a pilot in the Fleet Air Arm during the war and joined B.E.A. in 1946 as Manager of the Continental Division. Later he became General Manager of Continental Services and in 1951 Director of Movements; in 1952 he was appointed Controller of Operations, and in March this year Deputy Chief Executive. In his new post he succeeds Peter G. Masefield, who resigned from B.E.A. last November. In the interim Lord Douglas of Kirtleside, B.E.A. Chairman, has also been acting as Chief Executive.

● **The re-organization of B.O.A.C.** has been completed with the appointment of Basil Smallpeice, 47, to the new post of Managing Director. Smallpeice joined B.O.A.C. in 1953 and was Financial Comptroller under Sir Miles Thomas. He became Deputy Chief Executive in 1954.

● **Sark,** a tiny island in the English Channel, plans to impose a ban on helicopters. A motion submitted to the island's Parliament claims that a helicopter service "would do more harm than good". A London company has proposed a Guernsey-Sark service.

● **A civil aviation controversy** is developing in Italy. Several days after Defence Minister Taviani announced in the Italian Senate the establishment by his Ministry of a Secretariat for Civil Aviation independent of the General Secretariat for Military Aviation, Minister for the Merchant Navy Cassiani accepted a motion by Senator Artisco recommending the amalgamation of merchant shipping and civil aviation into a Ministry of Navigation (Ministerio della Navigazione). The action has aroused disapproval in civil aviation circles, where it is interpreted as an attempt by the Merchant Navy to gain control over civil aviation.

● **Marco Polo** is to be the name of the new Venice Airport to be built at Tessera. The name was chosen by the Consortium for the Development of Air Transport in Venezia, with Senator G. Caron in the chair.—Construction and operation of the airport will probably be the responsibility of the Venice Port Authority (Provveditorato al Porto di Venezia), which is expected to set up a separate Airport Administration. However, the final decision rests with the Ministry of Defence "Air".—The Consortium has recommended that Venice-Lido airport should continue to be available to light aircraft.

INDUSTRY

● **S.N.C.A. du Sud-Est** has announced the following details of its production programme, in connection with the first flight of the SE. 212 *Durandal* light-weight delta-wing interceptor: prototypes: a second *Durandal* is under construction; two SE.3200 helicopters are in order; a second *Caravelle* is flight testing; and two additional prototypes are being built (one for fatigue testing, the other for static tests). Quantity production: twelve *Caravelles* are being built for Air France; production of 90 carrier-based *Aquilon (Sea Venom)* fighters is nearly completed; and a batch of 180 *Alouette II* helicopters is being built for the three armed services. In addition, S.N.C.A.S.E. is working on a $12,000,000 contract from the U.S. Air Force in Europe for spares for the F-84F jet fighter and its reconnaissance version, the RF-84F. The company also participates in the following production programmes: fuselages for the *Mystère IIC*, the *Mystère IV A*, the *Super Mystère B2* and the Fouga CM.170-R, as well as ailerons, flaps and fuselage noses for the *Vautour* jet bomber. Further-

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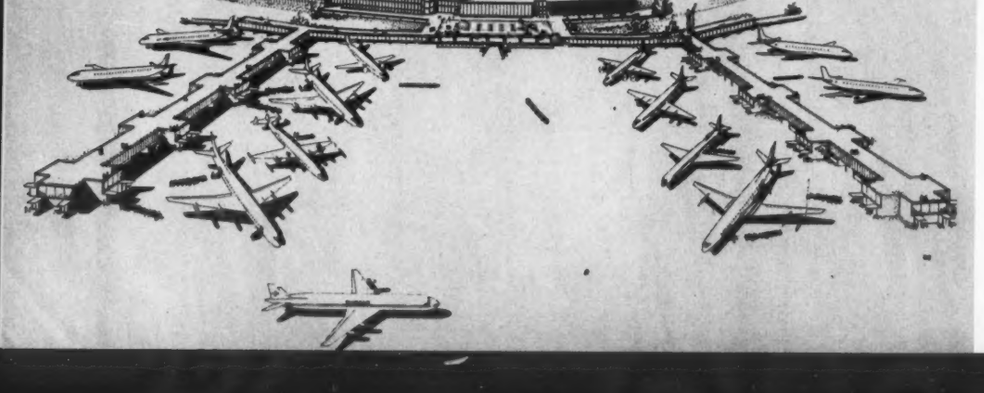
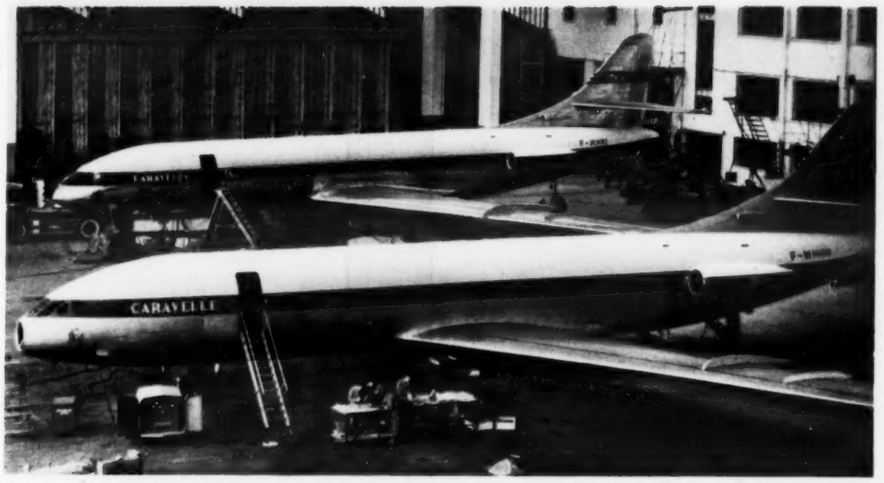
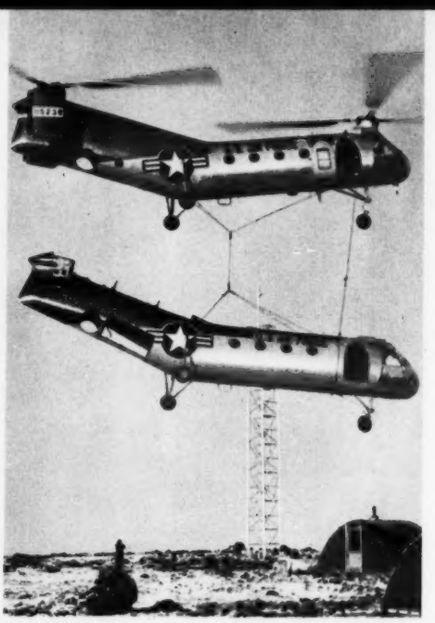
Zurich-Kloten Airport as it will look in 1960. The second expansion phase includes the enlargement of the transit hall and the addition of two finger docks to the apron. Cost: 180,000,000 Swiss francs.





The first and second prototypes of the SE.210 *Caravelle* medium-stage twin-jet commercial transport in S.N.C.A. du Sud-Est's large hangar at Toulouse-Blagnac. Up to April 30th the first prototype had flown a total of 404 hours. The second prototype made its first flight on May 6th.



Vertol H-21 *Work Horse* helicopters daily carry men and material to the early warning radar stations in Alaska. An H-21 which had been damaged while landing being transported to the repair base by another *Work Horse*.

more, S.N.C.A.S.E. is responsible for the maintenance and assembly of H-19 helicopters, the repair of F-84E, F-84G and T-33 aircraft, the decocooning of F-84Gs and RF-84Gs for U.S.A.F.E., the French Air Force and the Norwegian Air Force. Finally, it is also engaged in the reinforcing of fuselages for MD.315 transports.

● **The Convair Division** of General Dynamics Corporation is to build a new $40,000,000 plant near Sorrento Canyon, north of San Diego, to house an autonomous organization devoted to research, development, manufacturing and testing of the *Atlas* intercontinental ballistic missile. The buildings to be erected will provide approximately 1,000,000 sq.ft. of floor space. Convair has an Air Force contract for the construction of the *Atlas* I.C.B.M. hull and tanks. The project already employs several thousand engineers, technicians and production personnel.—The Sorrento Canyon facility will be the second within the Convair organization devoted exclusively to missiles. The Pomona, Calif., plant produces the *Terrier* surface-to-air missile for the U.S. Navy and Marine Corps.

● **Rocketdyne Division, North American:** The Propulsion Field Laboratory in the Santa Susana Mountains, 35 miles northwest of Los Angeles, was recently opened to the press for the first time. The centre is operated by the Rocketdyne Division of North American Aviation Inc. and is financed jointly by the U.S. Air Force and North American. Task: development and static testing of rocket motors for various Air Force, Army and Navy guided missiles projects. For static tests the motors are suspended in giant steel rigs on the side of the mountain. Several of these rigs are already in operation, and others are in construction.—Built in 1946, the Field Laboratory has been running since 1948. First tests of rocket motors began early in 1950.

● **Orenda Engines Ltd.,** subsidiary of Avro Canada Ltd., will complete a $7,700,000 expansion programme by the end of this year. The programme involves the following major additions to existing test facilities at Malton, Ontario: six new development test cells, with provision for extending the number to eight; a high altitude test facility, which will permit engine testing in the rarified cold atmospheric conditions encountered at high altitudes; an aerodynamic test facility, which will incorporate a wind tunnel for testing airfoil design for engine blades; a combustion facility, for testing performance and efficiency of engine and afterburner combustion. At Nobel, near Parry Sound, there will be a test facility for developing afterburner mechanical designs and a test cell for investigation of internally cooled turbine blade design under conditions similar to those in the engine. Completion of the project will enable Orenda to conduct about 90% of its testing with its own facilities.

● **Lockheed Aircraft Corp.** has awarded contracts to four aircraft firms to manufacture complete sections of the U.S. Air Force F-104 jet fighter. About 40% of F-104 manufacturing effort is represented in the sub-contracting programme, which is comparable in size to Lockheed's sub-contracting on the F-94C, T-33 and T2V-1. The companies to receive sub-contracts are: Beech Aircraft Corp., Wichita, Kan., aft fuselage; Goodyear Aircraft Corp., Arizona Division, Litchfield Park, Ariz., nose section; Rheem Manufacturing Co., Downey, entire tail assembly; Temco Aircraft Corp., Dallas, Tex., complete wing. The mid-fuselage and forward fuselage segments will be built at Lockheed's jet aircraft assembly facilities in Burbank and Palmdale. Final assembly and flight test will be handled at Palmdale.

● **Hughes Aircraft Co.** has started a move to transfer its entire multi-million dollar manufacturing and assembly plant in Culver City, Calif., to a new 42-acre site in El Segundo. The transfer is expected to be completed in June, and will enable the company to centralize its manufacturing. Research and Development will remain at Culver City, ultimately to expand into a larger division. Purchased from American Motors Corp. for a reported $3,000,000, the new plant covers 10 acres of floor space. Cost of improving the site was estimated by Hughes at $1,000,000. The entire move is being cloaked by a security system in which Hughes has made special preparations to have electronic equipment routed from Culver City to El Segundo at staggered hours and via different highways.

● **The Glenn L. Martin Co.,** of Baltimore, Md., reports that a new version of its B-57 twin-jet bomber, a target-towing aircraft designated B-57E, has made its first flight. If necessary, the B-57E can be converted in a short time into a bomber.

● **Curtiss-Wright Corp.** has received from Pan American World Airways an order for two flight simulators valued at $1,000,000 each. One is to be for the Douglas DC-8, the other for the Boeing 707. Delivery is scheduled for 1958.

Left to right: Hermann T. Poeschl, Manager of Lear Electronic GmbH, Munich-Riem; William P. Lear Jr., Manager of Lear S.A., Geneva; L. C. Boussard, I.C.A.O. Chief of Public Information, has been appointed Chairman of the United Nations Film and Television Board and its associated specialist agencies. The appointment was made at the Rome meeting of the U.N. Public Information Committee; Will W. White has been elected a Vice President of Esso Research and Engineering Company, New York, and will serve in a consulting and advisory capacity on all questions related to aviation petroleum products. He will also be responsible for informing the aviation industry about the activities of Esso Research and affiliated firms.

Douglas C-133A heavy transport.

S.N.C.A. du Sud-Est's SE.212 *Durandal* delta-wing fighter.

AIRCRAFT AND ENGINES

● According to recent unconfirmed reports, the Canadian *Avro CF-105* delta-wing supersonic fighter has a gross weight of around 34 tons, will fly at some 1,500 m.p.h. and have a range of 1,500 miles. It will be fitted with two Orenda PS-13 jets, each of which delivers a thrust of roughly 20,000 lbs. without afterburner and 30,000 lbs. with. The PS-13 is said to be built on the twin-spool principle. The CF-105 is reportedly designed to fight at 60,000 ft. and will be equipped with guided missiles and a fire control system designed by Hughes Aircraft Co. in the United States.—No prototype proper will be built; the first aircraft off the line next spring will have full production equipment.

● The second prototype of the *SE.210 Caravelle* twin-jet medium-stage commercial transport built by the French firm of S.N.C.A. du Sud-Est, began flight testing at Toulouse on May 6th. The first flight lasted 1½ hours. Test Pilots Nadot and Galy were at the controls.

● The improved *Nord 1405 Gerfaut II,* derived from the *Gerfaut I,* began flight testing in mid-April. Power plant is a SNECMA-Atar jet with reheat.

● The *Tupolev Tu-104* twin-jet commercial transport is evidently equipped with a thrust reversal device. It has been observed to taxi backwards under its own power.

● Carrier trials of the two new British carrier-based fighters, *Vickers-Supermarine N.113* and *de Havilland D.H.110* have been completed.

● A3D-2P and A3D-2Q are two new versions of the *Douglas A3D Skywarrior* light-weight twin-jet Navy bomber. A3D-2P is a special version for photo reconnaissance, and A3D-2Q is used for radar counter-measures.

● *Supersonic propellers* are being tested at Cornell Aeronautical Laboratory. The main problem with these propellers, which are designed for speeds of up to 8,000 r.p.m., is to prevent blade vibrations which might easily lead to fatigue rupture in the thin blades used.

● Four versions of the *Frye F-1 Safari* four-engined transport, the prototype of which is scheduled to begin flight testing in the spring of 1957, are offered: a passenger version with accommodation for 51 passengers and a "Vistaramic" lounge in the nose, a freight version, a combination version for mixed passenger and freight transport, and an "Executive" version.

● S.N.C.A. du Sud-Est's *SE.212 Durandal* light-weight delta-wing fighter began flight testing on April 20th.

● *Orenda Engines Ltd.,* of Malton, Ontario, announces an increase in time between overhauls for the *Orenda 11* and *Orenda 14* engines. The increase is 100% for the *Orenda 11* (fitted in the CF-105) and 50% for the *Orenda 14* (fitted in the *Sabre 6*).

A.G.A.R.D. Seminar in Munich: Professor Theodore von Kármán, Chairman of N.A.T.O.'s Advisory Group on Aeronautical Research and Development (centre) in conversation with W.G.L. Secretary General W. Ennenbach and Dr. Wattendorf, A.G.A.R.D., Paris (left), Dr. Th. Beneke of the West German Federal Defence Ministry and Captain E.G. Sharkoff of A.G.A.R.D., Paris (right).

● The *Hispano Suiza R.800* jet engine has completed a 20-hour test, during which it was run for 10 hours at its take-off power of 3,130 lbs. thrust and for 15 minutes at excess speed. The R.800 is later to be fitted with an afterburner which will increase power by about 30%.

● The *Pratt & Whitney J-52* jet engine, which is to be fitted in the projected Douglas DC-9, has a twin compressor and is said to deliver a thrust of 7,500 lbs.

● A project for a *combination power plant* consisting of a pulse-jet and a ramjet has been patented in the United States.

● *Zlin 226* is the designation of a new all-metal sports two-seater with 160 h.p. engine. It has a gross weight of 1,275 lbs., is designed for a max. speed of 144 m.p.h. and appears to be a development of the Zlin 126 *Trener* two-seat low-wing monoplane.

GUIDED MISSILES

● The following are representative costs of U.S. guided missiles: Martin *Matador* $85,000, Convair *Atlas* $1,250,000 (without warhead), Hughes *Falcon* $25,000 to $50,000, Philco-Martin *Sidewinder* $5,000, Douglas-Sperry-Raytheon *Sparrow* $10,000, Aerojet-General *Aerobee* $30,000, Martin *Viking* $250,000.

● Two *Soviet guided missiles* are said to be in service or about to go into service: one of them is reportedly suitable for launching from submarines and has a range of about 1,500 miles. The second—T-2 or M-103—is apparently a two-stage ballistic missile with a range of about 1,800 miles, largely based on the wartime German A-4 and A-9 developments. It is also reported that work on a three-stage long-range weapon, the T-3, for a range of 5,000 miles is under way.

● The *Convair SM-65 Atlas* intercontinental ballistic missile is expected to be fully developed by 1960, and substantial stocks should be available by 1965.

Production version (with modified wing leading edge) of the Avro *Vulcan* four-jet V bomber.

SOBEH-2 *Kolibrie* helicopter of Nederlandse Helicopter Industrie, Rotterdam. The rotor is driven by ramjets.

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. . . are fitted to over 100 Vickers Viscounts in airline operation.

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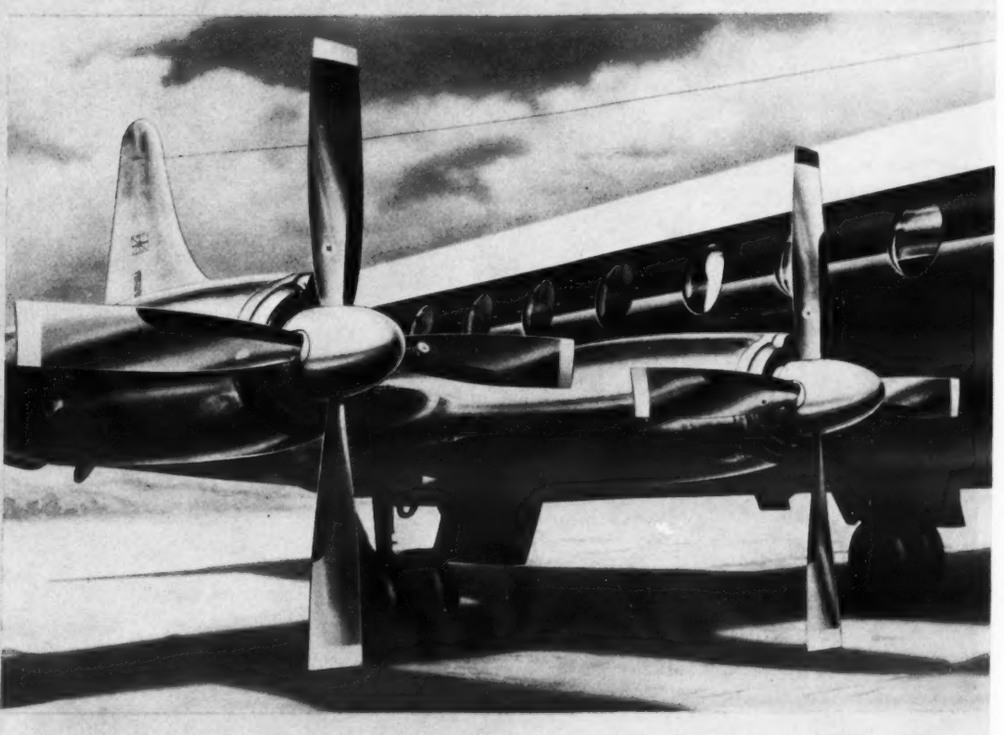

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Around the World

SAS SCANDINAVIAN AIRLINES SYSTEM is among 14 leading world airlines which will soon fly the new Convair Model 440 *Metropolitan*. Shown above is the first of 11 to be delivered to SAS. The total number ordered by airlines already exceeds 75.

Hamilton Standard reversible Hydromatic propellers are used on the new Convairs, as they are on more than 90% of the world's commercial airliners. The Model 440 will carry 44 to 52 passengers and will cruise at about 290 mph. The two engines are Pratt & Whitney Aircraft R-2800 Double Wasps.

Other airlines soon to fly the Convair Model 440 include Sabena Belgian World Airlines, Swissair, Braniff International Airways, Continental Air Lines, Delta Air Lines, National Airlines, Real S.A. (Brazil), Aero O/Y (Finland), Alitalia (Italy), LACSA (Costa Rica), Iberia (Spain), LAI (Italy), and Eastern Air Lines.

with United Aircraft

LARGEST CARGO CARRIER IN PRODUCTION, the Douglas C-133, can carry a load of about 100,000 pounds. The four 6,000 horse-power turboprop engines are Pratt & Whitney Aircraft T-34s, already tested in Douglas C-124 and Boeing C-97 cargo aircraft as well as in Lockheed transport types. The new U.S. Air Force C-133 has a wingspan of nearly 180 feet and is 148 feet 2 inches long.

ADVANCED HELICOPTERS now on duty in Europe with the U.S. Seventh Army are Sikorsky H-34s. This cargo type helicopter can carry 14 to 17 men or payloads of about two tons. The commercial version of this helicopter, the Sikorsky S-58, has been ordered by airlines in Europe and the United States for scheduled passenger and cargo service.

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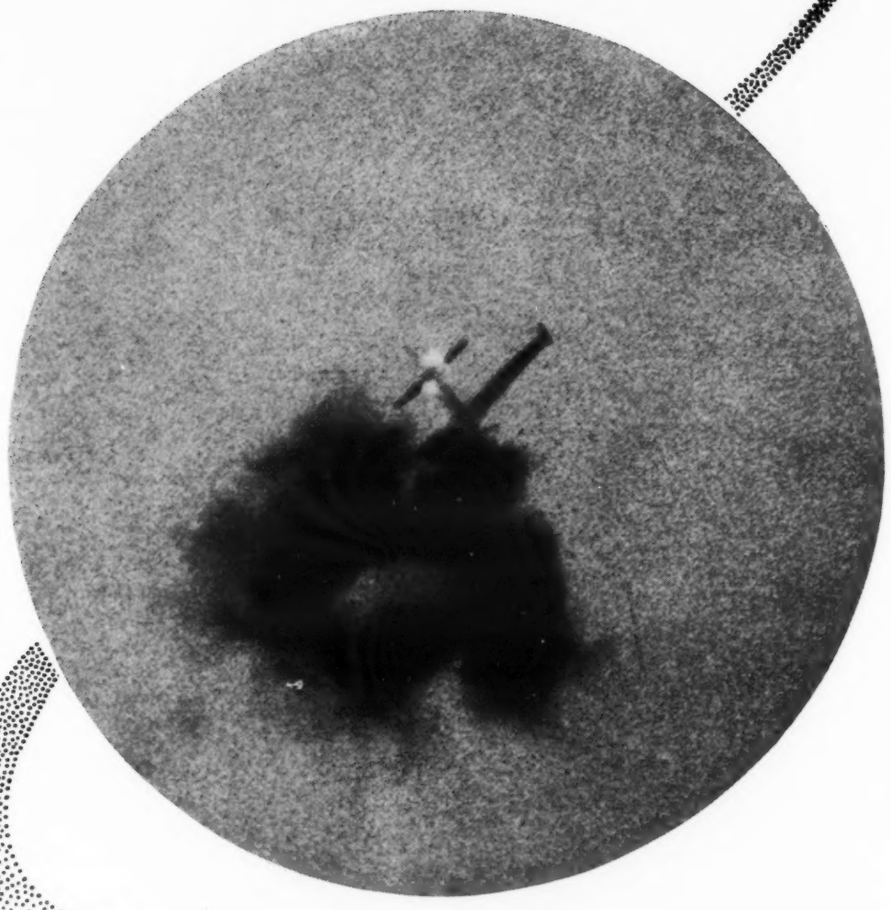
ACHIEVEMENT

The Fairey Fireflash



FAIREY

was the first British Company to design, develop and manufacture a guided weapon which destroyed a target aircraft. This weapon—the " Fairey Fireflash "—is now in production for the Royal Air Force.

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The Role of the Stable Platform in Inertial Navigation

by Dr. C. J. BREITWIESER, Vice President, Lear, Inc.

Almost everybody who has had a course in physics will remember the fundamental laws of uniformly accelerated motion, according to which velocity is the product of acceleration and time, while distance is the product of velocity and time. From this it follows that distance equals one half the product of acceleration and the time squared.

If we have had a little more extensive course in physics, we will also know that, when the motion is no longer uniformly accelerated, we can still compute the velocity and distance travelled by integrating the acceleration over time, once to get velocity and twice to get the distance.

Thus, assuming that we can accurately measure the acceleration of a body in three mutually perpendicular directions, and then accurately and continuously integrate the measured quantities over time, we shall be able to determine the position and velocity of the body in space at any one time, relative to some initial position.

It would seem almost that such a person could, if he wished, design an inertial navigation system, which is a mere matter of calculating where a given mass will be if acted upon by various forces over a known period of time, much as astronomers predict the orbits of heavenly bodies. The fact is that scientists have had to wait for many new tools before they could utilize Newton's laws of motion for inertial navigation of actual vehicles in space.

Today, however, relatively accurate inertial navigation is feasible within reasonable weight and volume for the equipment. Given a starting point, a small black box, such as that shown above, now enables an aircraft or missile to know its location, attitude, ground velocity and track at any time along an erratic course through space. Properly linked to external computers and control surfaces, this makes possible automatic navigation of the vehicle over long ranges entirely on its own.

It needs no radio signal from the outside. No celestial observations. No radar fixes. No ground facilities. No programmed flight path. Emits no radiation. Wherever the carrying vehicle goes, through gusts and buffets and a hundred arbitrary changes of course, the inertial navigation system knows where it has been, where it is, and how far it must go in a specific direction to reach a predetermined destination, even if that destination were halfway around the world.

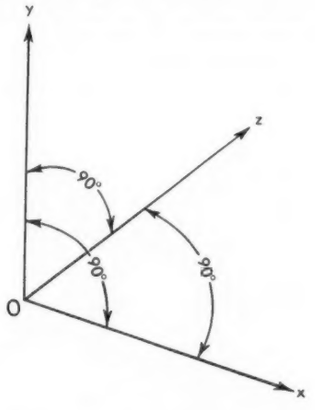
Involves Recent Advances in All Physical Sciences

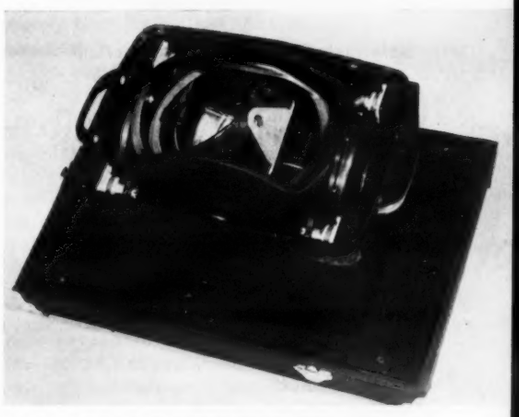
Most of the new tools that made this possible have been added very rapidly in just the last decade. A description of an operative inertial system is much like a news digest of recent advances on many technical frontiers. Nobody a generation ago could have predicted the specialized materials, testing equipment, miniaturization techniques, circuitry innovations, assembly tolerances and gyroscope accuracies that today are common. None could foresee our present ability to generate a meaningful electronic signal from extremely small accelerations and then to amplify, modulate, integrate and even commit that signal to memory. Today, airborne accelerometers are capable of delivering such signals with uncertainties of the order of 10^{-6}. None, in fact, could have foreseen any need for such things, since they relate only to the guidance of an aerial vehicle which is assumed to be deprived of any guidance intelligence from the outside. Such a vehicle might be a missile or aircraft over enemy territory, anxious to maintain radio silence or to deprive the defenders of any opportunity to " jam " its guidance.

The technical triumph which such an airborne system represents is chiefly one of miniaturization, of extreme accuracies in machining, balance and assembly tolerances, with six gyroscopic devices whirling at thousands of r.p.m. in different directions simultaneously, while all are nested snugly together under hermetic sealing and pouring out " intelligence " of many kinds. This is a stable platform.

Our discussion here, intended for laymen unfamiliar with such systems, will concern primarily this gyro-stabilized platform which provides a constant data reference plane as the black box moves through space, since upon this platform all else depends.

Fig. 1: A set of three mutually perpendicular vectors forms the basic element of a stable platform.





Mock-up of a three gyro—three axis platform.

The techniques which measure, integrate, and transmit acceleration data from this reference platform are wonderful, too, but in about the same sense as the lever was when Archimedes said, " Give me a place to stand and I shall move the world." The stable platform for the first time provides a place to stand while measuring and integrating the forces acting upon a body in space.

The Orthogonal Vector System

Put in another way, the function of the stable platform is to provide a system of three mutually perpendicular vectors that are space stabilized. *Fig. 1* illustrates the vector arrangement. Such a system is known as a space or spatial reference. It is perhaps easier to explain a space reference by establishing the concept of a terrestrial reference and then comparing the two.

A common form of terrestrial reference is the carpenter's plumb bob, which is used to establish a line normal to the earth's surface. *Fig. 2* depicts the earth as it would look to an observer from a point in space. Note that when the plumb bob is held in four different positions over the earth, it always points to the center of the earth, no matter whether it is held over the North Pole or " down under " at the South Pole. In this manner the plumb bob establishes the " local vertical."

Referring now to *Fig. 3*, again the earth is seen as it would look to an observer in space, but in this case a space reference vector " A " is aligned with a plumb bob located over the North Pole. The space vector " A " will, however, always remain parallel to itself and will always point in the original direction. Study of *Fig. 3* shows that at the Equator

vector " A " would be at right angles to a plumb bob suspended at this point.

In these discussions of terrestrial and spacial references, it will be noted that only one of the three mutually perpendicular vectors was dealt with. If the system of three mutually perpendicular vectors is used as a terrestrial reference, the vectors may be oriented as shown in *Fig. 4*—namely, the vertical, East-West, and North-South. Likewise, the spatial reference would at all times have its other two vectors maintained mutually perpendicular to the vector " A " shown in *Fig. 3*.

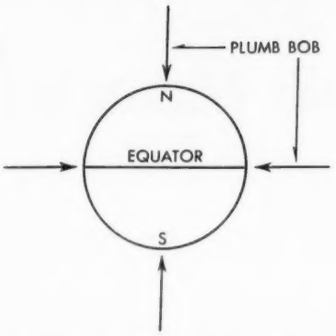


Fig. 2: *Concept of a Terrestrial Reference:* Note that the plumb bob always points to the center of the earth whether it is held over the North Pole or " down under " at the South Pole. This establishes local vertical.

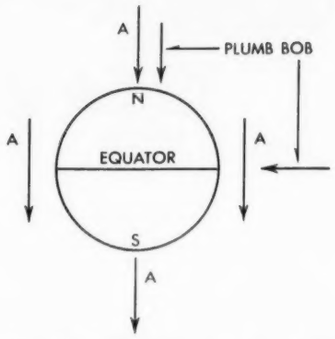


Fig. 3: *Concept of a Spatial Reference:* In this illustration the Vector " A " is aligned with the plumb bob to point to the center of the earth of the North Pole. However as this vector is moved around the earth, it remains parallel to this original position and does not point to the center of the hearth as does the plumb bob. Thus it is seen it establishes a direction in space.

Scientists Evolve Many Design Approaches

Many ways have been developed to reduce the concept of a stable platform to practice. The first ventures used enough machinery to fill an average room. All make use of the stabilizing properties of a gyro. Some platforms have two displacement gyros; some have three. Some platforms have three gimbals (this is also known as a 3-axis stable platform); some platforms have four gimbals (this is also known as a 4-axis stable platform).

Following are some types of stable platforms :

1. *3 Gyro - 3 Axis (Abbott Type)*
   (With and without accelerometers.)
2. *3 Gyro - 4 Axis (Abbott Type)*
   (No gimbal lock.)
3. *2 Gyro - No Gimbal Lock*
   (In reality, a directional gyro stabilized by a no-gimbal-lock vertical gyro.)
4. *3 Gyro - 3 Axis*
   (A directional gyro vertically stabilized by two single-degree-of-freedom gyros.)

Before examining the make-up of a stable platform, let us look briefly at a single gyro. Such a device has two most useful properties : its resistance to any change of direction of its spin axis ; and its ability, by setting up a processional velocity around a gimbal axis, to measure precisely any moment which is being exerted toward altering the direction of the spin axis. Instead of moving the spin axis in the sense of the moment, a proportional rotating (precessional) motion results around a gimbal axis which is at right angles to both the torque axis and the spin axis.

A directional gyro with its horizontal spin axis pointed North, for example, would be sensitive to any rotation of its carrying vehicle toward East or West. It is the vertical axis which is being monitored in a directional gyro.

Thus, precession is a true proportional reaction to any rotational movement of a space vehicle. The fact that the reaction occurs around a perpendicular axis of the gimballed, spinning wheel is a manifestation of gyroscopic phenomena which needn't be analyzed here.

The point to bear in mind is that the gyro's precession characteristic has been adapted to measuring either the *amount* of any rotation around the axis which it is monitoring, as in a *displacement* gyro, or the *rate* of such rotation, as in a *rate* gyro.

Abbott Type is Representative Hardware

Now let us take a close look at a three-gyro, three-axis platform. The particular configuration chosen is known as the Abbott Type. Once this type of a platform is understood, the variations possible become much clearer.

The " stick " diagram of *Fig. 5* shows schematically the essential components and their arrangement to make up a three-gyro, three-axis platform. Not that the stable platform proper is the innermost frame, and that it has mounted upon it three single-degree-of-freedom displacement gyros. It might be well to point out that common terminology gives two meanings to the words " stable platform ". One meaning of the term designates the entire assembly—gyros, signal elements, the gimbal structure and all parts that are installed within the hermetically sealed can. The second meaning given to the term is to designate just the innermost frame, which is gyroscopically stabilized.

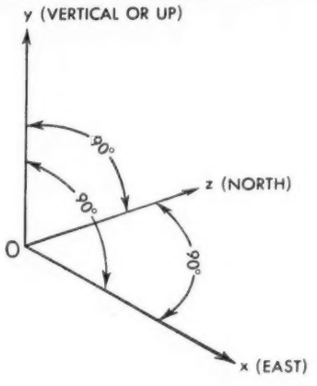
The platform is suspended in a gimbal assembly ; working from the inside out we have the azimuth gimbal (remember, this is pivoted to monitor the vertical axis), the pitch gimbal, and finally the roll gimbal. The roll gimbal is in turn suspended in an outer frame, which is used to mount the entire assembly in the vehicle that carries the stable platform.

Again referring to *Fig. 5*, note that each gimbal has associated with it a single torque producing device at one end, and a signalling device such as a synchro or a resolver at each end. Though they are not shown in this over-simplified diagram, there are slip rings, brushes and bearings at each gimbal joint. Mechanical features such as these will be treated elsewhere.

The gyros are mounted on the platform in a fashion as indicated in some detail by *Fig. 6*. Each gyro has freedom to move $\pm 15^{o}$ about its precession axis.

The gyros are arbitrarily assigned and identification letter ; usually the " A " gyro is the azimuth gyro and the letters " B " and " C " are given to the other two gyros which stabilize the platform proper in a " pitch and roll " sense. *Fig. 6* treats one gyro only, but it illustrates the fact that there is a torquer and an electrical pickoff installed on the precession axis of the individual gyro.

Fig. 4: Application of a system of three mutually perpendicular axes as a terrestrial reference. One axis (oy) is aligned with local vertical, the second (ox) is aligned to point East, the third (oz) thus points North.



Three Gyros Function Identically

Each gyro is assigned the function of stabilizing the platform in one of the three axes. It will be noted from *Fig. 5* that the spin axes of all three gyros lie in the horizontal plane. The " B " gyro's spin axis is perpendicular to the spin axis of the " C " gyro. The " A " gyro spin axis is 45^{o} to the other two. Furthermore, the precession axis of the " A " gyro is horizontal, while the precession axes of the other two gyros are vertical. This arrangement dictates that the " A " gyro stabilizes the platform in azimuth, the " B " gyro stabilizes in pitch, and the " C" gyro provides stability in roll. Should the direction of flight be turned 90^{o}, the assignments for the " B " and " C " gyros are interchanged, in a manner to be explained later.

To understand how a single gyro stabilizes the platform about one of the axes, let us refer to *Fig. 6*. To be technically accurate let us further assume that we have the vertical axis (the azimuth axis of the platform) situated at some point on the equator with it so aligned that the arrow on the platform proper is pointed North. If a disturbance which would manifest itself as a torque appears about the azimuth axis, it would tend to cause a drift or misalignment of the two arrows. The disturbing torque is generally caused by friction or accelerated mass unbalance about the stabilized axis (azimuth axis in this example). This torque will also cause the gyro to move about its precession axis. Were this disturbing

torque to continue, the gyro would continue to precess, changing the angle between the spin and stabilized axes from a right angle (90°), with a resulting decrease in its stabilizing effectiveness.

Disturbing Torques Compensated to Maintain Stability

To prevent this from happening and to counteract low-frequency or steady torques, an electrical pickoff is mounted between the gyro housing and stabilized frame. The output signal from this device is the input to an alignment amplifier.

The output of this amplifier excites the variable phase of a two-phase induction motor torquer in such a direction as to counteract the disturbing torque and realign the platform to North. The gyro itself counteracts the effect of high-frequency or transient disturbances. Each of the other two gyros has its own alignment amplifier, and the operation of the gyro stabilizing circuit is identical to the one just described.

With reference again to *Fig. 5* the gimbal freedoms are as follows: azimuth (or innermost) 360°, pitch (middle) ±85° maximum, and roll (the outermost gimbal) 360°.

Coding Resolver Function

With reference to *Fig. 5*, it will be noted that there are two resolvers on the azimuth axis of the platform. In the Abbott Type of stable platform it is necessary to use one of these resolvers as a coding resolver. It was stated in a previous section that each gyro had its own alignment amplifier to correct for unwanted torques about a specific gimbal axis. If we initially aligned the stabilized platform proper Northward and happened to fly the airplane with its roll axis headed Northward all the time we were using the platform, then the "B" and "C" gyros would always stabilize the pitch and roll axes respectively. But should we change the airplane heading 90° and fly East, the stabilized platform maintains its North heading and the "B" and "C" gyros would now be interchanged and would detect torques about the roll and pitch axes, respectively, but would apply the corrective torque to the wrong axes, or to the pitch and roll axes as before.

To perform an automatic switching function for the two gyros we use the coding resolver. This coding is accomplished by exciting the pitch and roll electrical pickoffs with 0° and 90° voltages, respectively, combining the roll- and pitch-gyro error signal into the two alignment amplifiers and comparing the signal with a reference voltage from the coding resolver.

One stator of the coding resolver is excited with a 0° voltage, and the other is excited with a 90° voltage. The output of each rotor is used as the reference voltage for one of the amplifiers; the resolver rotor outputs remain constant in amplitude but vary in phase with the airplane heading. The amplifiers then deliver power to the gimbal torquers (variable phase winding) that is proportional to that component that is 0° in phase or 180° out of phase with the reference to the particular amplifier.

Electrolytic Switch

In order to make the stable platform a terrestrial reference, a gravity sensing device is installed on the platform proper. It may be a two-axis electrolytic switch used to control the amount of voltage and the phase of the voltage supplied to the variable phase of the torquer. However, the torquer involved is not the gimbal torquer that was discussed above. It is the torquer that is installed partly on the gyro itself and partly on the stabilized platform. This is known as the gyro torquer. *Fig. 6* schematically shows this torquer toward the upper left-hand side of the page.

The Schuler Pendulum

In accelerated motion, the simple pendulum does not suffice to establish a true vertical reference for the platform. This is because the pendulum tends to align itself with the instantaneous dynamic vertical, which is the resultant of acceleration due to gravity and of vehicle accelerations.

However, as Max Schuler showed many years ago, if the period of the pendulum, the platform, and associated control devices can be made equal to 84 min., then the platform becomes insensitive to vehicle accelerations, and tends merely to oscillate about the true vertical with this period.

The significance of the 84-minute period is associated with the fact that this is just the period of a pendulum whose length is equal to the Earth's radius. The 84-minute period is accomplished by selecting the proper constants for platform erection and pendulum damping.

Azimuth Orientation of the Stable Platform

To orient the stabilized inner frame in azimuth to some external reference a comparison resolver external to the platform is matched to the second resolver installed on the azimuth axis of the platform. Any difference in the angular positions of the two resolvers produces a signal from the external resolver which is amplified and supplied to the variable phase winding of the azimuth gyro torquer. This torquer is, of course, partly on the azimuth gyro ("A" gyro) and partly on the stabilized frame. This torque is applied about the precession axis of this gyro and causes movement about the azimuth gimbal axis.

Two Gyro — Four Axis Platform

Probably the simplest instrument which merits the title of "platform" is the two-gyro, four-axis device shown by the stick diagram of

Fig. 5: Stick diagram for a three-gyro, three-axis stable platform (Abbott type.)

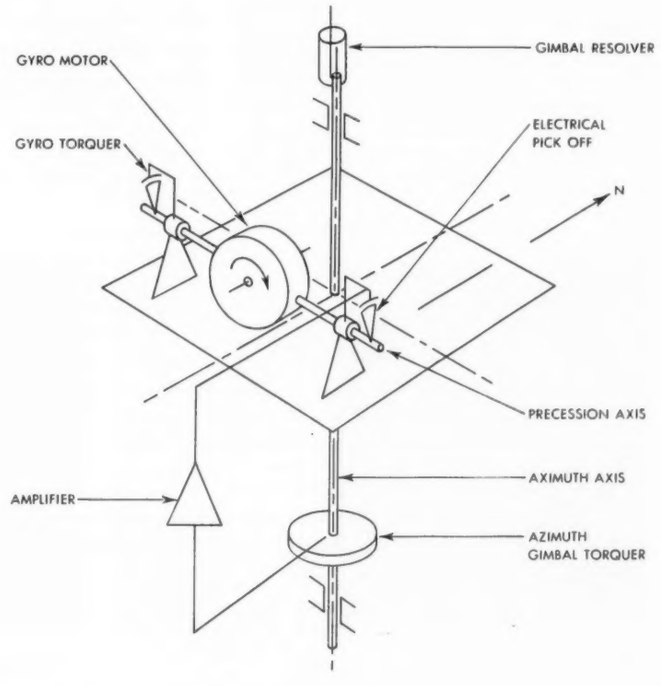


Fig. 6: Schematic showing how a single gyro stabilizes the platform about one axis. (The example shown is for the azimuth gyro providing stabilization about the azimuth axis.)

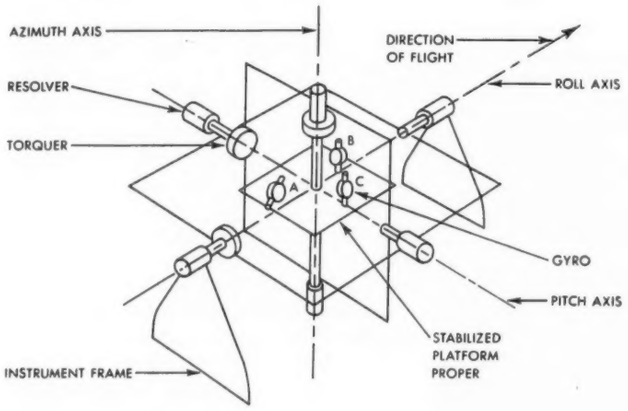


Fig. 7. As shown by the diagram, the instrument consists of a " no-gimbal-lock " 3-axis vertical gyro which is used to stabilize a directional gyro. The vertical and directional gyros have a common roll gimbal which is servo driven. The pitch pick-off of the vertical gyro is used to provide a signal for pitch stabilization of the directional gyro. The second gimbal of the directional gyro is thus a space-stabilized platform. It is obvious that this type can be made only in the four-axis configuration, as the directional gyro must be stabilized in both pitch and roll axes to provide true azimuth signals.

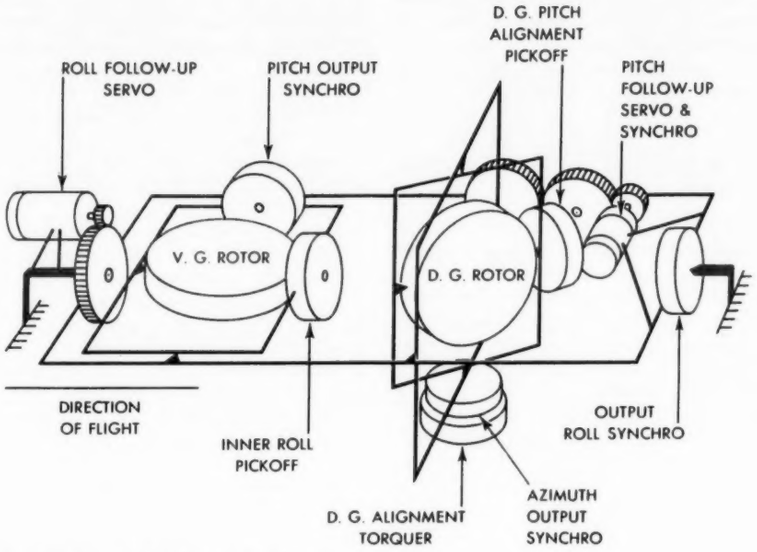


Fig. 7: Two gyro—four axis platform. Three gyro—three axis platform.

How a No-Gimbal-Lock Stable Platform Works

A basic limitation of a 3-axis stable platform results from the possibility of " gimbal-lock " in certain extreme aircraft attitudes. This condition, in which two axes of gimbal freedom coincide, can be avoided by the addition of a fourth axis of freedom. This is achieved by gimballing the 3-axis stable platform in an outer gimbal about an axis coincident with the stable platform roll axis. A servo motor drives this outer gimbal relative to the three-axis system, in accordance with a displacement signal developed by a variable-reluctance pick-off mounted between the first and second gimbals on the inner roll axis, in such a manner as to maintain the inner roll gimbal in its normal position orthogonal to the pitch gimbal.

During periods of high pitch maneuver, switching operations are required to provide operation of the outer roll gimbal. A segment switch, located on the pitch axis of the stable platform, removes excitation from the roll-axis pickoff when the pitch angle is near $\pm 90^{o}$, and switches control of the outer gimbal. Provision is also made in the roll-servo system, by the use of the pitch switch, for reversing the phasing of the roll pickoff excitation when the pitch angle exceeds $\pm 93^{o}$. This action prevents operation of the roll servo from an unstable null when in inverted flight. If high pitch angles occur simultaneously with yaw maneuvers, it would be possible to " tumble " the platform if appropriate switching were not performed on the inner roll axis.

The Flight Path as a Summation of Accelerations

Now we have created a platform which will remain directionally oriented and level with respect to the earth throughout a flight. If the platform is level and pointing north inside a missile that is rising straight up, it will remain in that exact position as the missile enters its trajectory, cruises and descends. A Lear platform did this in December, 1955, operating perfectly during an extended high-altitude missile flight. This was one of the first such flights of a production-type 3-axis stable platform.

We are ready, therefore, to consider the second phase of our design problem—that of measuring and integrating all vertical, East-West, North-South accelerations throughout a flight so that a missile upon reaching its destination, perhaps thousands of miles away, will be at least within sight of its target.

Two most familiar ways of measuring acceleration use a pendulum or a spring-restrained mass. The pendulum has definite limitations in measuring large accelerations due to its angular displacement which may pick up some gravity acceleration. The spring-restrained mass is prone to inaccuracies in measuring low accelerations if the spring is made strong enough to handle the big ones. Techniques are being developed to over-come the shortcomings of the strong spring by using a weak spring which is mounted so it can be torqued to resist heavy accelerations. The torque voltage needed to maintain null is then measured.

Another method, which avoids the shortcomings of the pendulum or spring-mass accelerometers, utilizes gyroscopic principles. This gave rise to our earlier remark that the inertial guidance platform might have six gyros mounted upon it.

This concept uses a precessional gyro of maximum accuracy, into which is built a precise amount of intentional unbalance about the inner axis. This unbalance produces a continuous and known rate of outer gimbal rotation per unit of acceleration. An electrical pickoff then measures the extent to which the gyro's outer gimbal has rotated. This is the time integral of the acceleration, or velocity.

Such data can then be electronically integrated continuously with data from either or both of the two other accelerometers. The resultant known flight path automatically resolves distance travelled, and to be travelled, to reach a predetermined destination.

None of this is as simple of actual attainment as it may appear. The effects of earth rotation, magnetic disturbances, and changing latitudes, and the maintenance of a true vertical in the presence of horizontal accelerations, all raise special problems. Also, the judgment of designers will vary as to emphasis placed, and penalty to be paid in weight, volume, reliability, complexity, or accuracy, for refining particular performance parameters. These decisions will in turn be influenced heavily by each specific application.

Therefore, the device described herein is necessarily generalized and omits the particular design characteristics which our own company has developed, since they are still proprietary secrets. It is hoped, nevertheless, that the layman reader may have gained a better understanding of the nature of the stabilized platform upon which inertial guidance depends. The earth-referenced technique discussed here is a proving ground for later guidance through outer space. There we might find it more convenient to orient our platform to two or more fixed stars, but we would maintain that orientation in about the same way. We still would have to deal with the fact that the terms " level " and " vertical " are always relative and seldom absolute. Even the North Star, for example, cannot occupy the same position for as much as a second. It has an absolute motion in space and a relative motion to fixed earth axes because of the earth's orbital and precessional motions.

Frederick B. Rentschler †

After a brief illness *Frederick Brant Rentschler*, 68-year old founder and Chairman of United Aircraft Corp., died at his winter home at Boca Raton, Florida, on April 25th, 1956. His life's achievement was mainly to have provided the major contribution to overcoming an epoch in which the " motorists " seemed to be doomed always to trail a few steps behind the aerodynamicists. For Rentschler building engines was not a " profession " in the ordinary sense, not a mere means of earning money or making a livelihood. Engines were his destiny, and it is for this reason that to his countrymen he became known as " Mr. Horsepower ".

Born in Fairfield Township, Ohio, on November 8th, 1887, he graduated from Princeton University in 1909. During World War I, in 1917, he was called to Washington by the (then) U.S. Army Air Service to assist in solving the problem of procuring an efficient U.S. aircraft engine. After the war in 1919, he formed the Wright Aeronautical Company, became its first General Manager and Vice-President and, soon after, its President. However, after his father's death in 1924, he left Wright Aeronautical to take over the management of the family steam and gas engine business at Hamilton, O. If he had now wanted to lead an easy, comfortable life, he could have settled down at Hamilton and no doubt would have been lost to aviation. But as little as one year later he raised his anchor again, returned to the East Coast and at Hartford, Conn., formed the Pratt & Whitney Aircraft Company, the engine firm from which in 1929 —through the addition of the Sikorsky Aircraft and Hamilton Standard propeller divisions—emerged the United Aircraft Corp. The Chance Vought aircraft division which formed part of the concern for many years, became an independent firm again in 1954 and continues to flourish at Dallas, Texas.

Under Rentschler's determined management United Aircraft became the major engine producer of the international aircraft industry. During World War II Pratt & Whitney Aircraft Division supplied 50 percent of the U.S. forces' aircraft engine needs. Rentschler's workshops in 1925 produced the first U.S. air-cooled aero-engine (Wright Whirlwind) and thirty years later was in full production on the powerful jet engines which assure the qualitative need of the U.S. Strategic Air Command and will make possible the start of U.S. commercial jet air transportation.

Frederick Rentschler has passed away, but his company—which today employs 50,000 people—will continue to be guided by the principle which Rentschler set down a few years ago when America's forthcoming entry into the jet transport age became topical—" When the time comes," he said, " we will be ready."

Warm Work for Caracas...

Programme for I.C.A.O.'s Tenth Assembly

The Tenth Assembly Session of the International Civil Aviation Organization, due to meet in Caracas, Venezuela, in the second half of June, will face an extensive agenda. The subjects for discussion are in no sense routine matters that can be disposed of at more or less leisurely working sessions or informal tea parties on shady hotel terraces. This time the agenda includes problems whose solutions will inevitably have far-reaching effects on I.C.A.O. and its member States. Discussion will centre around I.C.A.O.'s present structure and *modus operandi* on the one hand, and the whole series of problems set by the coming jet transport age on the other.

The most important items on the programme can be summarized as follows :

1. frequency of general assemblies ;
2. period of office and working methods of the I.C.A.O. Council (in particular shortening the duration of meetings) ;
3. re-organization of I.C.A.O.'s administration ;
4. report of the Technical Committee (jet transport) ;
5. technical assistance to countries with under-developed aviation ;
6. activity of the I.C.A.O. Legal Committee ;
7. activity of the Finance Committee ;
8. relation between I.C.A.O. and the European Civil Aviation Conference at Strasbourg ;
9. international privileges for I.C.A.O. personnel.

Should I.C.A.O. be cast in a new mould?

The first three points on the programme are closely connected and all aim at simplifying and reducing the cost of I.C.A.O.'s work. The suggestion that a General Assembly should no longer be held annually but once every two, three or even four years was already put forward at the Seventh Assembly at Brighton in 1953, when it was argued that I.C.A.O.'s initial work was completed and it would now suffice for members to meet at longer intervals to take decisions ; the routine work could be left to the secretariat.

Easier said than done. There are certain provisions in I.C.A.O.'s statutes that are against this proposal and are difficult to revise. The budget is prepared on an annual basis, I.C.A.O. has to make annual reports on its activity to the United Nations Social and Economic Council, the I.C.A.O. Council's period of office is fixed at three years, etc. A compromise has been found in recent years, by calling a " big " Assembly outside Montreal every second year to discuss special problems of aviation, while the intermediate " small " Assemblies in Montreal dealt with routine administrative decisions within I.C.A.O. — The I.C.A.O. Council will now propose to the Tenth Assembly that this provisional arrangement be continued for another three years and a final decision left until the 1959 Assembly.

As regards the *composition of the I.C.A.O. administration*, the United Kingdom submitted

← *Dr. Edward Pearson Warner*, 61, who (as Deputy Chairman of the U.S. Civil Aeronautics Board) led the American delegation to the Chicago Conference in 1944 and helped create I.C.A.O., has been *President of the I.C.A.O. Council* for the past decade. He is reported to have decided not to stand for re-election for a further term.

Ernst Carl Robert Ljungberg, → 58, former head of Sweden's Civil Aviation Administration, joined I.C.A.O. in 1946 and took over the post of *Secretary General* at the beginning of 1952.

a written proposal on November 15th, 1955, to the effect that the present posts of President of the Council (now held by Dr. Edward P. Warner) and Secretary General (E. C. R. Ljungberg) should be abolished and the duties combined in the hands of a newly-appointed Director General. However, the United Kingdom will maintain its proposal only if the Council's working methods are first considerably simplified and steps are taken to make it unnecessary for the 21 Council member-States to keep permanent representatives at headquarters in Montreal.

So far Dr. Warner is sticking to his decision not to seek re-election as President of the I.C.A.O. Council. However that may be, it is still an open question whether he will really leave the controls of an organization which, despite many difficulties, he has guided to world-wide esteem. In any case it would seem to be premature to indulge in any form of " obituary ".

Routine work

The Tenth Assembly Session will naturally also have to deal with a mass of less spectacular business, the most important items of which are briefly summarized below.

I.C.A.O. Legal Committee : — The following subjects are at present under study by the Legal Committee (preparation of draft agreements) : aircraft collisions ; legal status on board aircraft on international routes ; leasing, chartering etc. of aircraft ; negotiability of air waybills. Matters not yet tackled but on the programme for future study are : assistance on land and sea ; general limitation of the operator's liability ; revision of the Rome Convention on the seizure of aircraft as security ; international execution of court decisions in air law. As a matter of interest it can be stated that the Legal Committee is already examining the legal problems of space outside the earth's atmosphere. The Legal Committee's report makes no secret of the fact that none of the conventions signed by member States has yet obtained the necessary number of ratifications : the Geneva Convention on the Recognition of Rights in Aircraft, which was signed by 27 States but has been ratified by only seven ; the revision of the Rome Convention relating to Damage caused to Third Parties on the Surface, which bears 26 signatures but has been ratified by only two countries ; the revision of the Warsaw Convention for the Unification of Certain Rules Relating to International Carriage by Air, which was also signed by 26 States but has so far been ratified by only one. Urgent measures are indicated to change this state of affairs.

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Finance Committee : — This Committee complains of the incomplete and dilatory fashion in which national aviation authorities prepare their reports and proposes the following working programme for 1957 to 1959 : standardization of airport charges (special session scheduled for the second half of 1956) ; charges for the use of air safety installations and services (special meeting between 1957 and 1959) ; preparations for multilateral agreements on commercial landing rights in scheduled international transport and on the regulation of mail and freight traffic ; statute for non-scheduled traffic, etc.

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I.C.A.O. and the European Civil Aviation Conference : — I.C.A.O. made a substantial contribution towards the secretariat costs of the first two sessions of the European Civil Aviation Conference, which has been set up by 19 European States to coordinate European air transport. The question now under discussion is to what extent the European Conference should be made dependent administratively on I.C.A.O. It has been suggested that all secretariat work should be taken over by I.C.A.O.'s regional office in Paris.

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International privileges for I.C.A.O. Personnel : — The main topic under this heading will be tax exemption for I.C.A.O. staff in the countries where they are stationed. No agreement has yet been reached with the Government of Quebec Province on tax exemption for I.C.A.O. personnel at the Montreal headquarters.

The coming jet transport age

In contrast to these more modest points on the agenda, the *Technical Committee's* report tackles the most burning problem in civil aviation, the coming introduction of jet airliners and its effects on airports, airways control, personnel training etc. The report is supplemented by an extensive *special programme of the Executive Committee* which is expected to be of decisive importance for future I.C.A.O. activities.

Both documents contain an impressive summary of the difficulties ahead : 1) there are not sufficient large airports (with adequate runways, handling facilities, fuelling services, accident service, fire-fighting facilities etc.) for the jet transports weighing up to 300,000 lbs. and carrying up to 150 passengers which will be coming into service in 1959-1960 ; 2) the new speeds of 500 knots—which, according to official American forecasts, will have risen to 870 knots within twenty years—will necessitate a radical re-organization of air traffic control systems and a fully automatic system of communications ; 3) the existing meteorological organization for high-altitude observations (except in North America, Western Europe and Australia) will be quite inadequate for the future cruising altitudes of 30,000 to 40,000 ft. ; 4) special requirements will arise from the expected increase in traffic by rotary-wing and vertical take-off aircraft, and from the general rise in traffic volume for fixed-wing aircraft, which is expected to double by 1960.

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How will this overwhelming mass of new tasks affect the working methods of I.C.A.O. and aviation planning by individual member States ?

As regards the work of I.C.A.O., both Technical Committee and Executive Committee believe that present methods will have to be completely revised. During the early post-war years it was possible to limit activities—despite the relatively rapid development of civil aviation—to the gradual preparation and introduction of I.C.A.O. Standards and Recommendations (14 annexes to the Chicago Convention). But now future problems are such that they cannot be solved merely by a progressive evolution and appropriate application of present Standards and Recommendations.

Turning to the question of planning by national aviation authorities, the report states that in future the old method of planning (and budgeting) the ground organization for only a few years ahead will no longer be adequate. I.C.A.O. suggests a " *minimum planning period* " of twenty years, stressing that even then individual projects can be applied to only two successive " aircraft generations ". An added difficulty is that the performance of aircraft in the design or development stage is normally kept secret for a certain length of time and thus cannot be allowed for from the outset in planning the ground organization.

Yet another difficulty arises from contradictory demands that airports should be located at some distance from urban areas, but that landing grounds for rotary-wing and vertical take-off aircraft should be as near the city centre as possible.

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In the opinion of the Executive Committee, the solution of these problems will require an increase in capital expenditure and in specialist personnel that cannot even be estimated at the present time. A special section of the Executive Committee's report is devoted to *financing*. As hitherto, the necessary funds will have to be provided primarily by the States on whose territory the new installations are set up and operated. However, in view of increasing aircraft range and the consequent expansion of route networks, there will be a growing number of States that will draw no economic benefits from the new air traffic control facilities. In these cases, the facilities will have to be financed by higher contributions from other I.C.A.O. member-States (technical assistance), or by direct contributions from the airlines using them. I.C.A.O. therefore proposes a substantial increase in charges for the use of air traffic control and other ground facilities (a suggestion that will probably be received by the airlines with mixed feelings). Another suggestion is that State-controlled or semi-State-controlled organizations might be set up to operate the air safety facilities on a more or less commercial basis.

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Technical assistance : — As already stated, successful change-over to jet transport will depend not least on a substantial increase in technical assistance for States with underdeveloped aviation. Such assistance measures have already been increasing in scope from year to year. During 1950, the assistance programme's first business year, I.C.A.O. used credits amounting to $200,000 (Canadian) for this purpose. For 1956 this sum has risen to $1,166,750. In 1956 a total of 32 States are claiming I.C.A.O. assistance (provision of experts to advise on ground organization problems ; personnel training ; grants for study trips ; supply of equipment, etc.). In addition to I.C.A.O., individual member-States and even some airlines have so far participated in the assistance programme.

Caracas,... a turning point

Whatever the decisions taken at the Tenth Assembly Session, it is clear that I.C.A.O. and its member-States are approaching a decisive phase of development. Ultimately the question at issue is whether world air transport will weather the coming jet age or will founder. This is no time for comfortable compromise solutions. However, I.C.A.O.'s achievements to date provide every reason for confidence that the task ahead will be mastered.

Book Reviews

Moderner Flughafenbau. Entwurf, Dimensionierung und Bauausführung von Landebahnen und sonstigen Verkehrsflächen. — By Dipl. Ing. Friedrich Kohl. Springer-Verlag, Berlin/Göttingen/Heidelberg, 1956 (German, 129 p., 101 illustrations, DM 24).

The weight of modern aircraft is approaching that of the heaviest locomotives, so that ordinary road-building techniques can no longer be applied to the construction of runways and taxiways. New calculating and construction methods for hard-surface runways to take undercarriage loads of up to 75 tons have been worked out in recent years and discussed primarily in Anglo-Saxon literature. The present book fills a gap in German writing on the subject and gives all essentials on the design and construction of airport surfaces.

After a brief summary of I.C.A.O.'s recommended standards for runways, taxiways and parking areas, attention is turned to the effect of jet aircraft on airport installations, heat stress on the surface, decomposition of asphalt etc. Certain of the author's statements, as for example the remark that the take-off runs of jet aircraft are more likely to be reduced than increased in the future, should, however, not be accepted without criticism.

Considerable space is given to calculating methods and experiments to determine the load capacity of rigid and flexible runway surfaces. Other chapters deal with drainage, protection against frost, reinforcing of foundations, and the most important earth moving equipment. Useful details on the construction of concrete surfaces are contained in the next section. The importance of mechanization is revealed by the fact that from 700,000 to 1,765,000 cu.ft. of concrete are used in building a modern airport. Finally there is a bibliography covering 173 titles.

All firms concerned with the construction of airports and military air bases, as well as airport operators, government agencies and the like, should find the present book a valuable source of information. Re.

World Aircraft Recognition Manual. — By C. H. Gibbs-Smith and L. E. Bradford. Putnam, London, in association with John de Graff, New York, 1956 (English, 269 pages, 15 shillings).

This manual is probably the first to attempt a classification of aircraft according to their wing shape—delta, swept, straight or rotary—and within these categories according to number of engines, wing position etc. No bad idea for the amateur aircraft spotter. It is another question whether this method is the best one for covering the aircraft of different countries. Re.

Paris—Treffpunkt der Welt. Kleiner Stadtführer. — By Hans Rathgeb. Verlag Gasser & Co., Rapperswil, Switzerland, 1956 (German, 174 pages, 25 photographs, 2 maps, Sw. Fr. 5.50).

To know Paris one must grow up in Paris. The traveller with little time—for example, the air traveller—who has not had this privilege, however, will be well served by this concise, intelligently arranged, pocket-size guide book. The alphabetical catalogue of streets, squares and places of interest appears to be particularly practical, since it will save a good deal of the time so often wasted in looking up references. Bon voyage ! He.

Books received

Astronautica Acta. Official organ of the International Astronautical Federation ; Vol. I, Nos. 1 to 4, and Vol. II, No. 1.—Springer-Verlag, Vienna, and I. R. Maxwell & Co. Ltd., London/Paris/New York.

*

Publications scientifiques et techniques du Ministère de l'Air. Distributed by Service de documentation et d'information technique de l'Aéronautique, Paris.

No. N. T. 57 : *Etude de la diffusion dans les gels à l'aide des isotopes radioactifs,* by Suzanne Cordier.

No. 307 : *Les applications scientifiques de la notion de régularité,* by Pierre Vernotte.

No. 308 · *Etude expérimentale des écoulements gazeux,* by Marie Merle.

*

Berich über eine Näherungstheorie der Strömung um Rotationskörper ohne Anstellung bei Machzahl Eins.—By F. Keune, Report No. 3 of the German Aeronautical Research Establishment. —Westdeutscher Verlag, Cologne and Opladen, 1955 (price DM 8.80).

Turbinenschaufeln aus Kunststoff für Kaltluftuntersuchungen. — By K. Leist and W. Dettmering, Report No. 4 of the German Aeronautical Research Establishment. — Westdeutscher Verlag, Cologne and Opladen, 1955 (price DM 12.30).

Strömung von Flüssigkeiten mit temperaturabhängiger Zähigkeit (Kühlung von Ölen). By B. v. Schlippe, Report No. 9 of the German Aeronautical Research Establishment. — Westdeutscher Verlag, Cologne and Opladen, 1956 (price DM 11.70).

Die Strömung einer Quellstrecke im Halbraum — eine strenge Lösung der Navier-Stokes-Gleichungen. — By E. Schmieden and K.-H. Müller, Report No. 10 of the German Aeronautical Research Establishment. — Westdeutscher Verlag, Cologne and Opladen, 1955 (price DM 8.80).

Ein Verfahren zur Untersuchung des Austauschvorganges in verwickelten Strömungen hinter Körpern mit abgelöster Strömung. — By A. W. Quick, Report No. 12 of the German Aeronautical Research Establishment. — Westdeutscher Verlag, Cologne and Opladen, 1955 (price DM 8.70).

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Thermodynamische Zustandsgrössen und Stoffwerte für Luft bei Dissoziationsgleichgewicht. — By H. J. Kaeppeler and H. G. L. Krause, No. 1 in the series of reports by the Research Institute for the Physics of Jet Propulsion. — R. Oldenbourg, Munich, 1954 (price DM 18.—).

Über die Wirtschaftlichkeit von Wasserdampfraketen als Horizontal-Starthilfen. — By H. H. Kölle, No. 2 in the reports issued by the Research Institute for the Physics of Jet Propulsion. — R. Oldenbourg, Munich, 1955 (price DM 24.—).

Zur Mechanik der Photonen-Strahlantriebe (German version). — By Dr. Ing. Eugen Sänger, No. 5 in the reports issued by the Research Institute for the Physics of Jet Propulsion. — R. Oldenbourg, Munich, 1956 (price DM 36.—).

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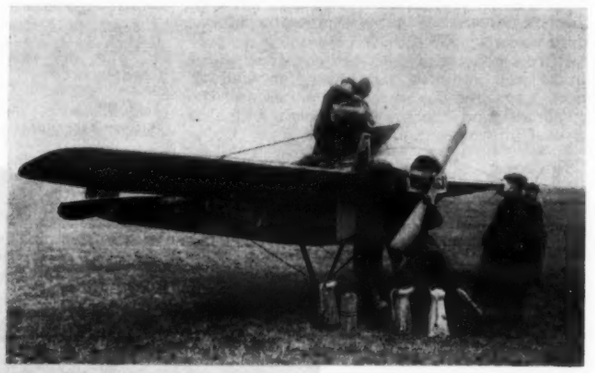

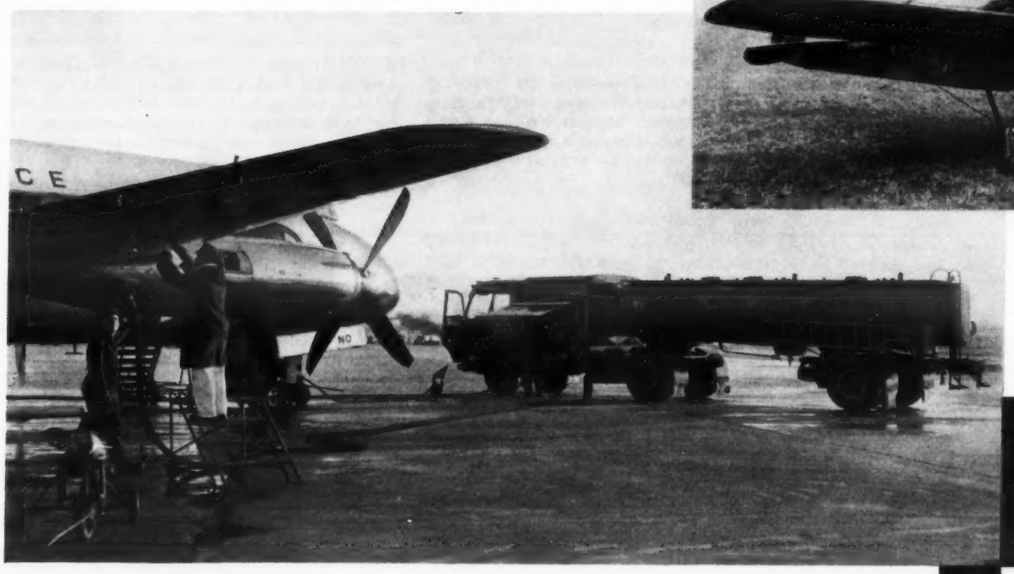

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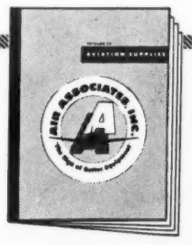

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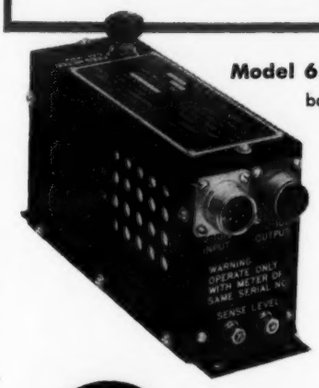

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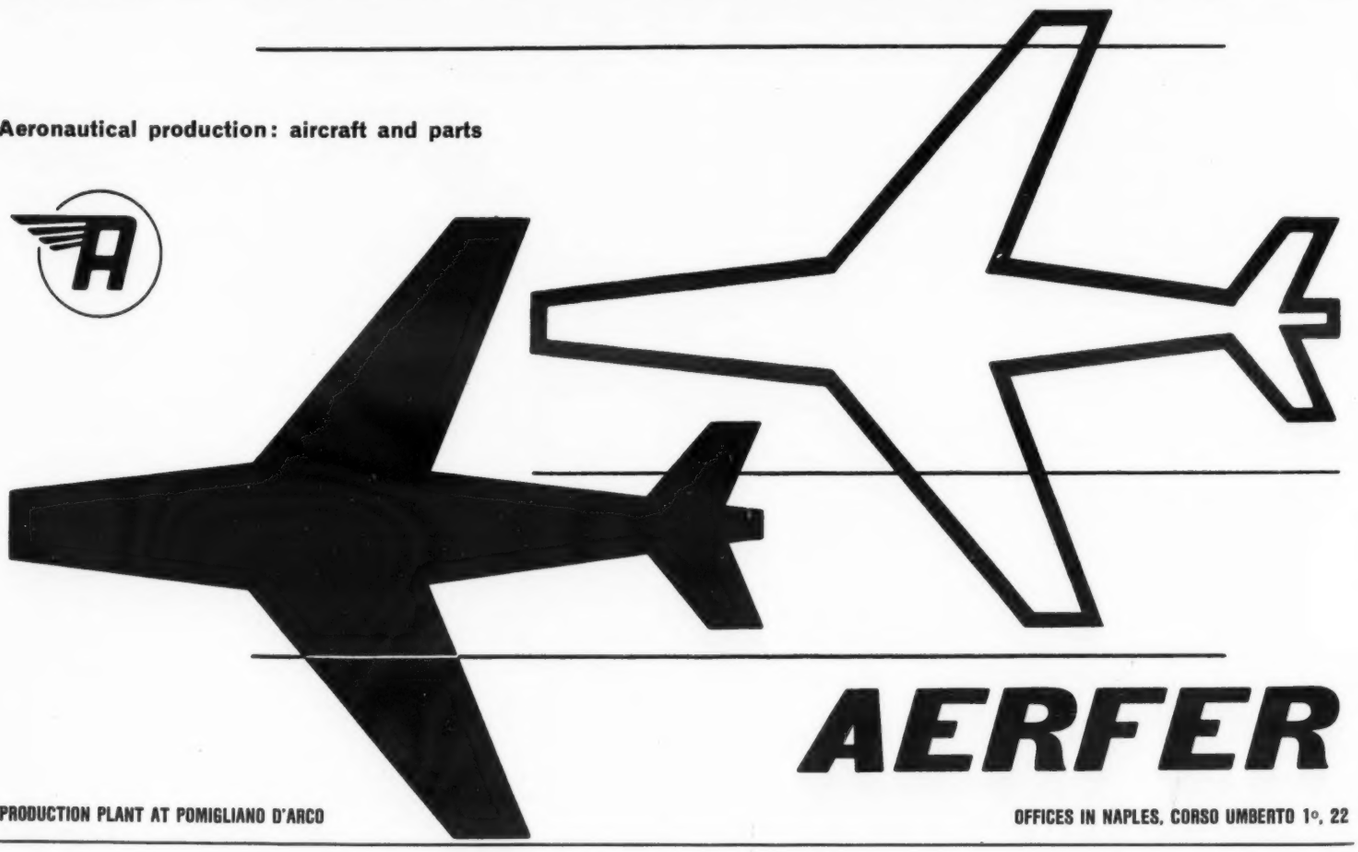

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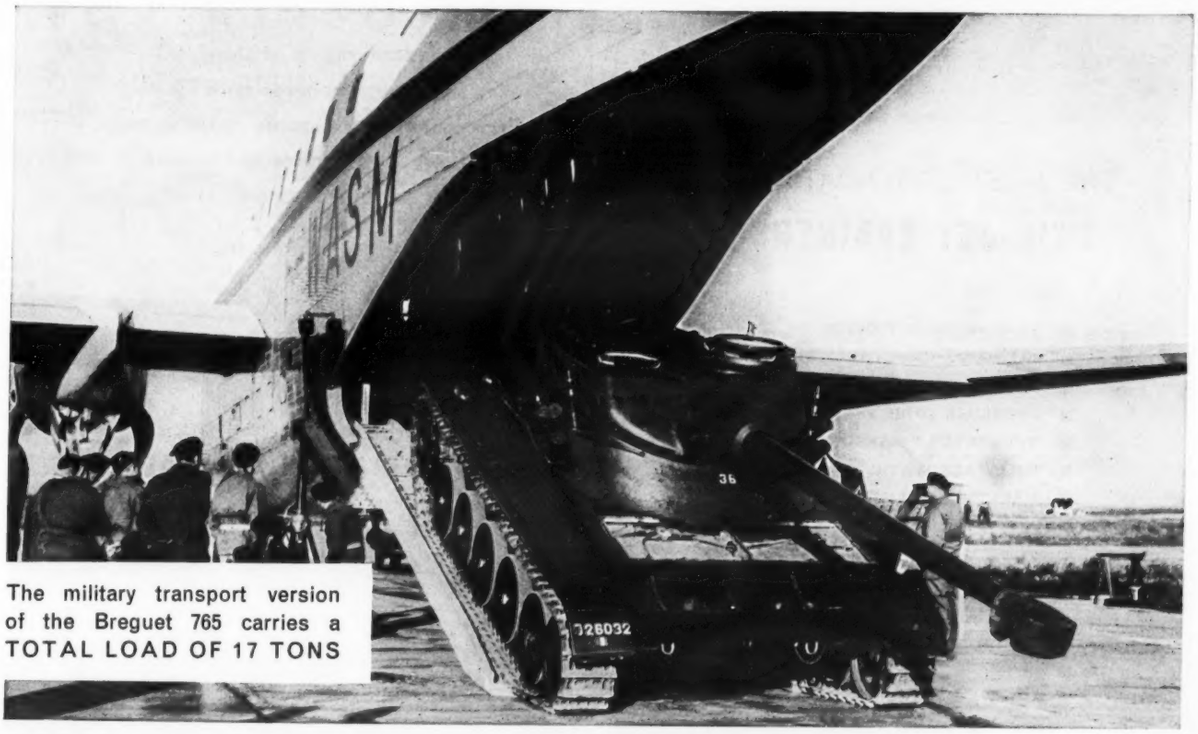

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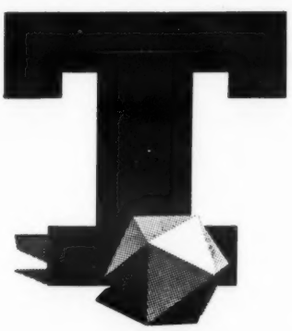
Calendar of Events

- ✱ **International demonstrations of agricultural and special machinery at the National Agricultural Machinery Centre, Mirafiori — September 29th and 30th, October 1st**
- ✱ **Eighth International Cinematographical Congress — October 1st, 2nd, 3rd.**
- ✱ **Eighth International Plastics Congress — October 4th, 5th, 6th.**
- ✱ **National Congress of the Associazione Meccanica Italiana — October 8th, 9th, 10th.**
- ✱ **International Technical and Scientific Press Show**
- ✱ **Third International Convention on Winter Road Traffic, Sestriere, January 1957**



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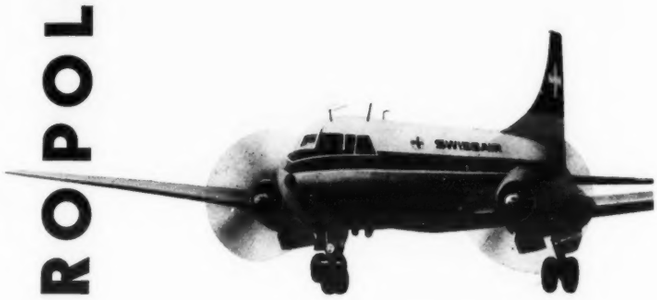

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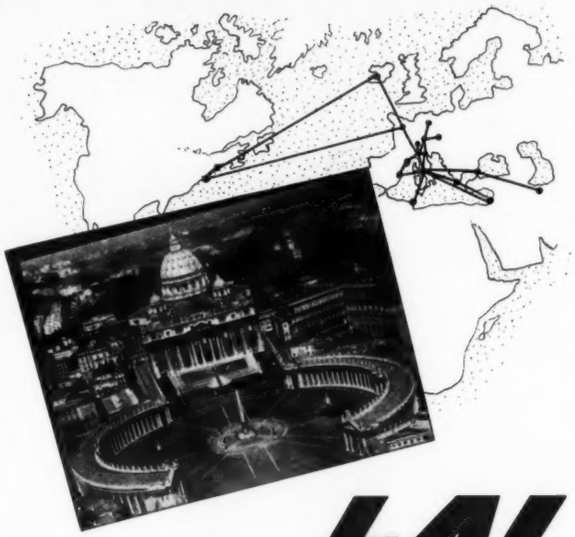

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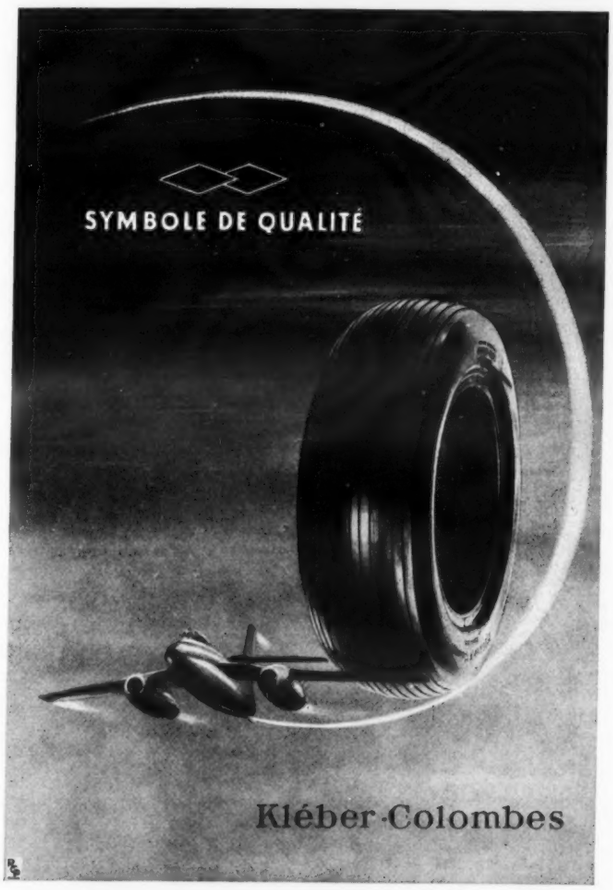

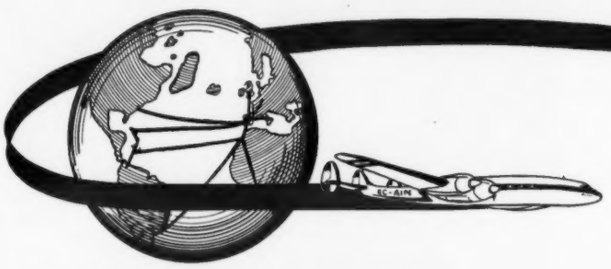

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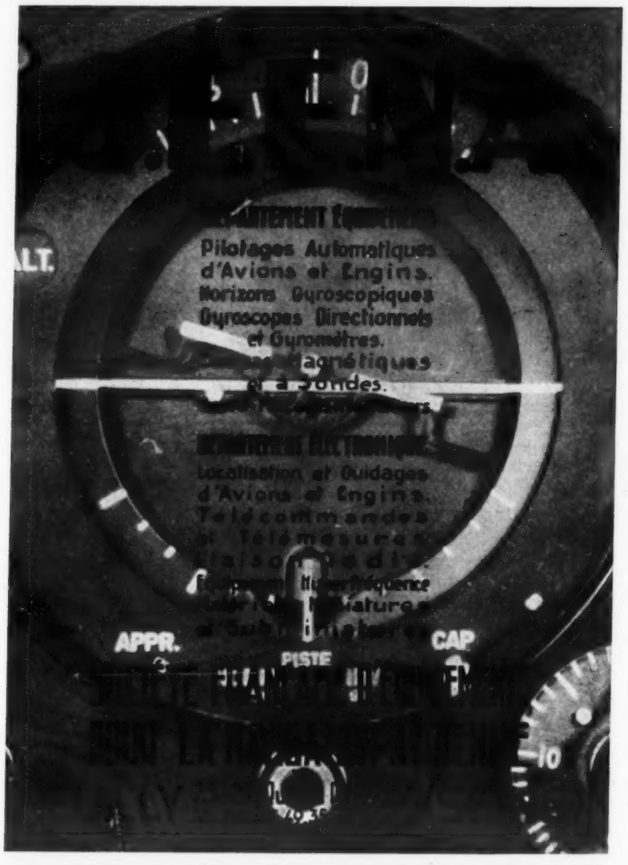

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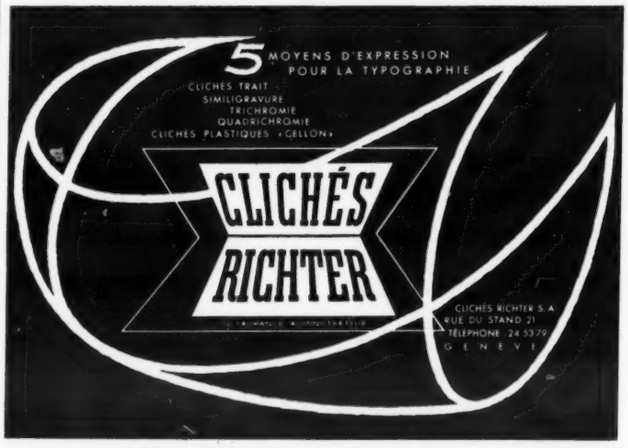

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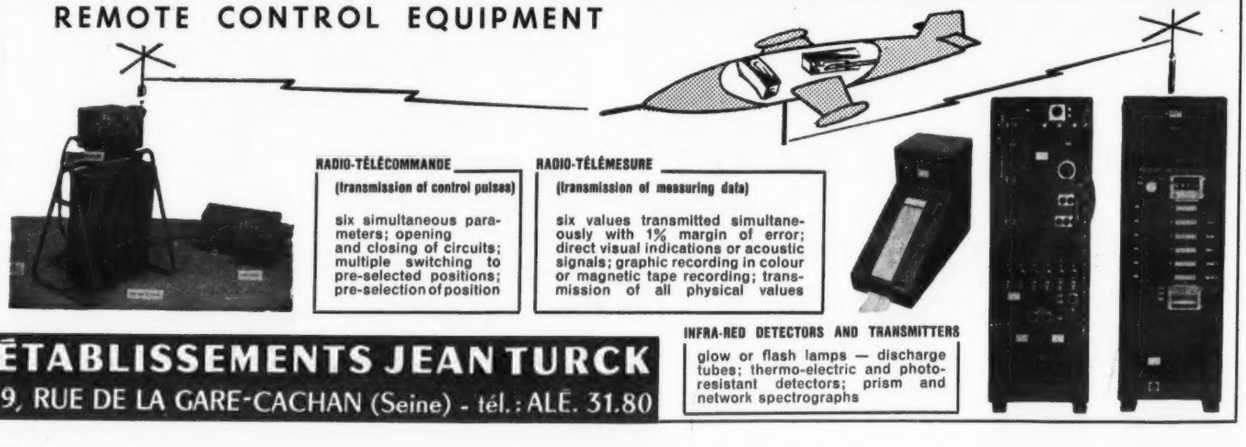

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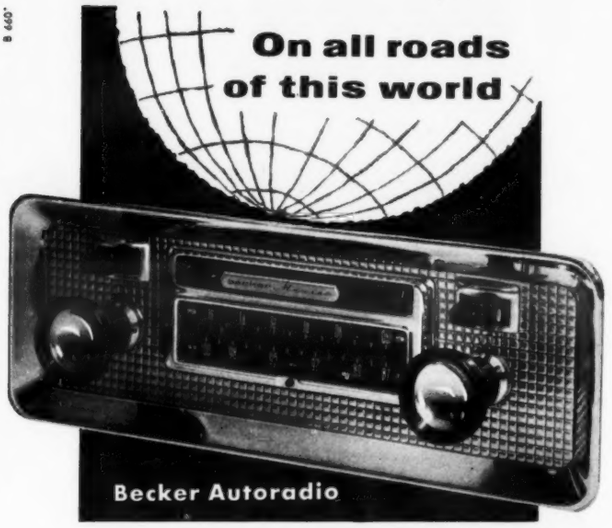

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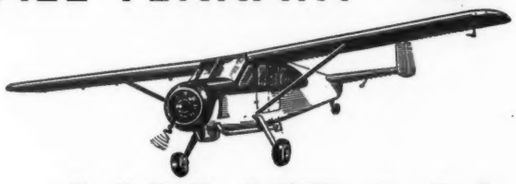

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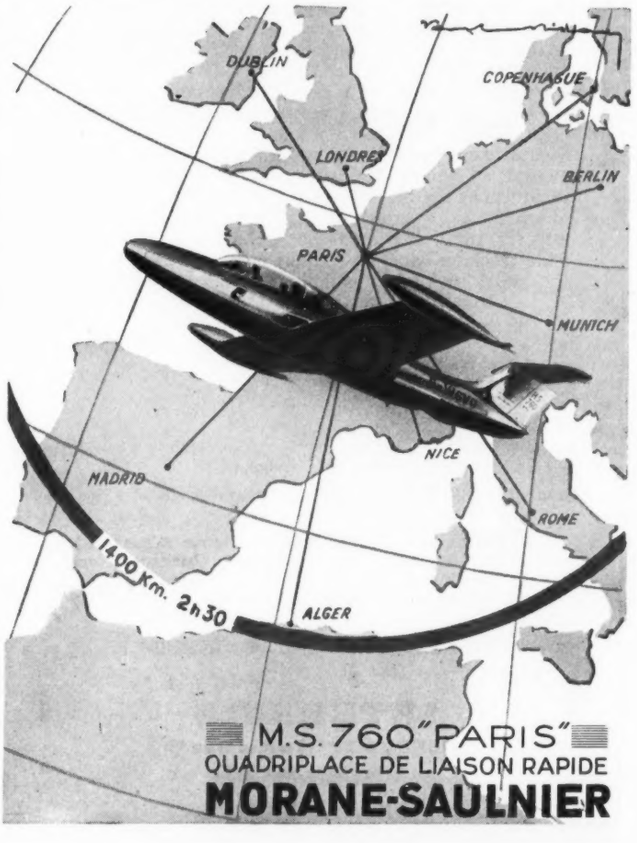

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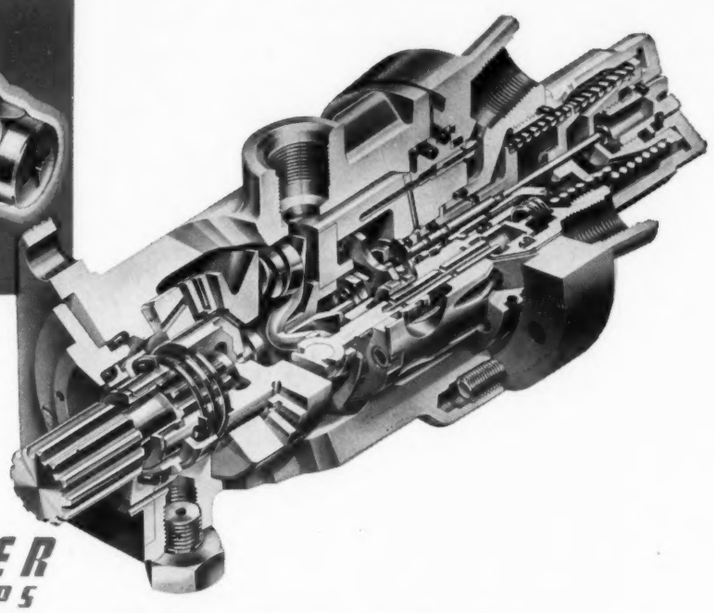

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